

Issued February 8, 1913.

U. S. DEPARTMENT OF AGRICULTURE,

BUREAU OF SOILS—MILTON WHITNEY, Chief.

IN COOPERATION WITH THE STATE OF WASHINGTON, M. E. HAY, GOVERNOR;
HENRY LANDES, STATE GEOLOGIST.

SOIL SURVEY OF THE QUINCY AREA,
WASHINGTON.

By A. W. MANGUM, CORNELIUS VAN DUYNE,
AND H. L. WESTOVER.

MACY H. LAPHAM, INSPECTOR IN CHARGE WESTERN DIVISION.

[Advance Sheets—Field Operations of the Bureau of Soils, 1911.]



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LETTER OF TRANSMITTAL

U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF SOILS,
Washington, D. C., June 24, 1912.

SIR: The accompanying report and soil map cover the survey of the Quincy area, Washington, one of the projects undertaken by the bureau during the field season of 1911. This work was carried on in cooperation with the Washington Geological Survey. Mr. E. J. Saunders, of the University of Washington, has contributed a valuable chapter on the climatic conditions existing in the area surveyed, and Mr. H. K. Benson, of the Washington Geological Survey, has also added a valuable chapter on the chemical analyses of the various soils encountered.

I recommend that the report and map covering this work be published as advanced sheets of Field Operations of the Bureau of Soils for 1911, as provided by law.

Respectfully,

MILTON WHITNEY,
Chief of Bureau.

HON. JAMES WILSON,
Secretary of Agriculture.

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MAP.

Soil map, Quincy sheet, Washington.

SOIL SURVEY OF THE QUINCY AREA, WASHINGTON.

By A. W. MANGUM, CORNELIUS VAN DUYNE, and
H. L. WESTOVER.

DESCRIPTION OF THE AREA.

The area surveyed lies a little southeast of the center of the State of Washington and comprises a large proportion of central and south-western Grant County, one township in the extreme southwest corner of Adams County, and a narrow strip on the west side of the Columbia River in Kittitas County. It is rectangular in shape, including townships 16, 17, 18, 19, and 20 north, ranges 23, 24, 25, 26, 27, and 28 east. It has an area of 1,123 square miles, or 718,720 acres.

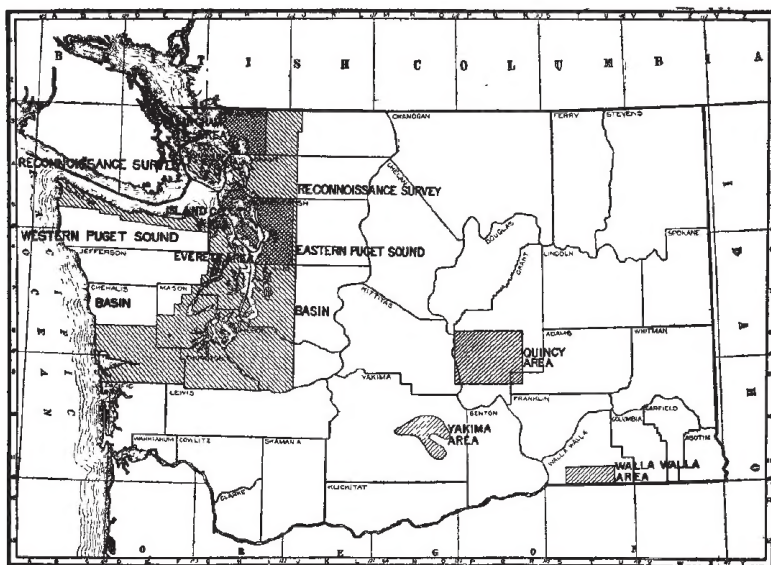


FIG. 1.—Sketch map showing areas surveyed in Washington.

The area taken as a whole consists of two plains, a northern and a southern, separated by a low range of hills. Immediately north of the northern boundary of the area the northern plain is terminated by a range of hills known as the Badger Mountains, lying parallel to the boundary, and on or immediately south of the southern boundary the southern plain is terminated by the steep and rugged northern slope of the Saddle Mountains. The range of hills dividing them has an east-west trend parallel to the northern and southern bound-

aries of the area. The main features trend east and west therefore, the plains consisting of east-west belts of lower country, the ranges of higher country. The two plains might be considered as parts of the same feature separated by the dividing ridge, the Frenchman Hills, which may be considered as standing on the plain.

The northern plain, known as the Quincy Valley, taken as a whole and without modifications which have been made subsequent to its formation, is a very smooth plain highest along its northern boundary and sloping imperceptibly southward to the north foot of Frenchman Hills. The eastern end of the southern boundary is a little lower than the western end, so that the general slope is southeastward. The difference in elevation between the northern and southern boundaries is less than 150 feet and the width of the plain from north to south is about 20 miles, the slope being not more than 8 feet per mile.

The Quincy Valley plain has been subjected to two kinds of surface modifications. Valleys have been cut into it and material has been piled up on its surface into low hills. On its western boundary is the deep, narrow valley of the Columbia River, which has been cut sharply into it to a depth of 700 feet. The Columbia trench, however, is singularly lacking in tributaries, only one or two cutting back from it into the plain and these are short. In the eastern part of the area there are a number of valleys, all of them shallow when compared with that of the Columbia, the widest being occupied by Crab Creek. Some of them are abandoned and some are bordered by low terraces. There are enough of these to produce a strong modification of the plain surface in this end of the area. Between these two ends the surface is singularly free from valleys.

The wind has built up on the surface of the plain and in the valley of Crab Creek a number of sand dunes. These are found mainly in its southeastern part and occur over about one-fifth or less of the total area of the plain. They begin on the western and northern parts of their area of occurrence as low mounds, increasing in height southeastward to the boundary of the plain.

The Frenchman Hills belt is about 2 miles wide and consists of a ridge of smooth rounded contour, rising to a maximum height of about 500 feet above the Quincy plain. Before the eastern boundary of the area is reached it has practically faded out so that it is scarcely noticeable along the valley of Crab Creek.

The southern plain, which will be called the Beverly plain, is from 6 to 10 miles wide, less than half as wide as the Quincy plain. Its upland surface lies at about the same elevation as the southern boundary of the Quincy plain. It differs from the latter, however, in having a much smaller proportion of smooth upland and in the

practical absence of sand dunes. It is modified to a greater extent than the Quincy plain, but the modifications are all of one kind. They are all the result of erosion. The valley of Crab Creek lies across its eastern end and along its southern boundary and is cut into it to a depth of about 600 feet. The valley of the Columbia lies across its western end. Each is about a mile in width, the valley of Crab Creek being a little the wider.

Cutting back from both the main valleys are a number of small valleys which have reached to nearly all parts of the plain, dissecting the greater part of it rather thoroughly.

West of the Columbia River in the southwestern corner of the survey is a small area of country essentially a part of and much like the Beverly plain in its surface features.

The principal stream of the region surveyed is the Columbia River, which follows a course near the western boundary and crosses the extreme southwestern corner of the area. The stream drains a very small proportion of the land along its course, as the greater proportion of the uplands slope to the eastward from the summit of the rolling hills which border the river valley. The second most important drainage outlet is the old river channel which crosses the eastern and southern parts of the area. Crab Creek, which follows this old channel, is an intermittent stream. Just above Moses Lake it contains running water, but on leaving Moses Lake it traverses an area of sand dunes, and from that point to its mouth it contains water only at intervals. Many small, dry, drainage channels, which serve to carry off the water at times of heavy rainfall, rise in the uplands and have their outlets in one of these main streams. The semiarid condition of the area has caused the thorough drainage of the land to be of minor importance, but if irrigation was practiced on an extensive scale a more thorough drainage system would be necessary in many parts of the area.

The population of the area consists almost wholly of settlers who have taken up homesteads or desert claims within the last 8 or 10 years. Many of these settlers come from the more thickly settled districts of Washington, but a large number from Minnesota and other north-central States.

Almost all of the land suitable for agriculture which was open to settlement has been taken up. The greater proportion of the area, however, is still very sparsely settled, and some sections, such as the area of sand dunes and the areas too rough or rocky to be of any agricultural value, are still almost uninhabited.

Quincy, a town of about 400 inhabitants, located in the northwestern part of the area, is the principal town. It is the local shipping point for all of the Quincy Valley lying west of the sand dunes and north

of Frenchman Hills. Ephrata, the county seat of Grant County, is located 30 miles east of Quincy, a few miles north of the northern boundary of the survey, and is the shipping point for a large proportion of the eastern and northeastern parts of the area. Winchester, situated 7 miles east of Quincy, and Trinidad, located just over the northwestern boundary, are small towns which are becoming of local importance. Beverly, situated in the extreme southwestern part of the area, with a population of about 300, is the principal town south of the Frenchman Hills, while Red Rock and Smyrna are small stations along the Chicago, Milwaukee & Puget Sound Railroad.

Two of the principal transcontinental railroads cross the area in a general east and west direction. The northern part of the area is traversed by the main line of the Great Northern Railroad. This line furnishes excellent transportation facilities for all of that part of the area lying north of the Frenchman Hills. The Chicago, Milwaukee & Puget Sound Railroad crosses the extreme southern part of the area. Throughout the western and central parts of its area the distance between these roads is about 30 miles. Some local shipping point on the latter line is within easy reach of every township in that part of the area which lies south of the range of Frenchman Hills.

The wheat and rye grown in the area are sold to local elevator companies at Quincy or Ephrata and later shipped to Seattle or Tacoma. It is either used by the local flour mills in these cities or shipped to various parts of the United States or to foreign countries. The fruits and vegetables grown in the area are sold on the local markets.

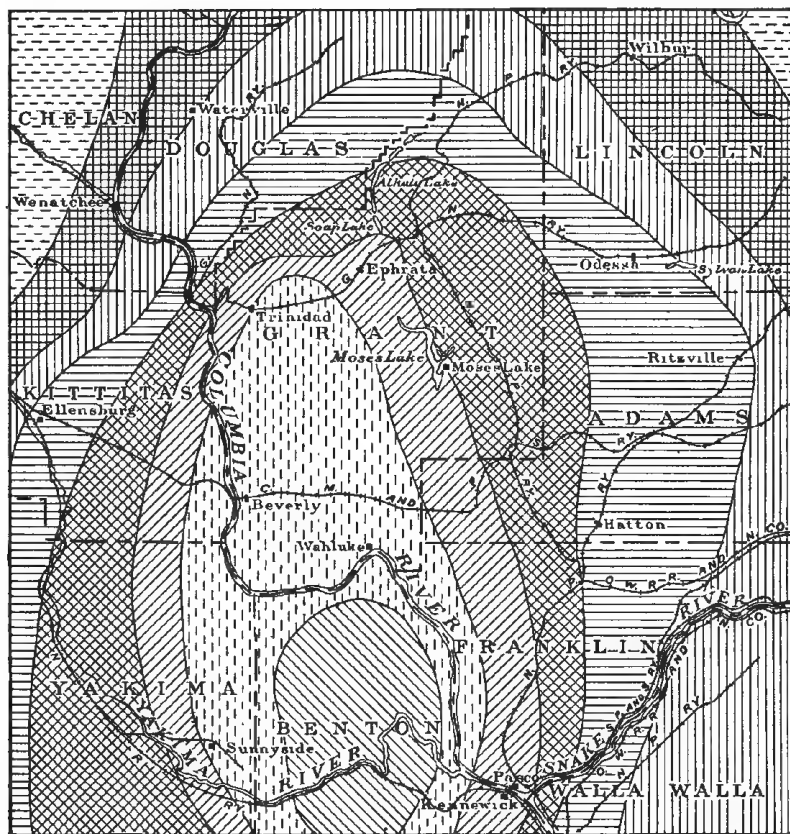
CLIMATE.¹

CLIMATIC CONDITIONS.

This section, lying east of the Cascade Mountains, in the Columbia River Basin, although not a great distance from the Pacific coast, has a climate as different from that of the section west of the mountains as if in a different part of the continent entirely. The influence of the topography and of the relation to prevailing winds is shown here to a remarkable extent. The high Cascade ridge to the west practically shuts this section off from the moderating effects of the ocean winds, which are such an important factor in the climate of western Washington. It also lacks the protection of the Cascades from the continental extremes of climate, especially the cold waves of winter that spread outward from the low-temperature cap of the interior, and is therefore subject to the low winter and high summer temperatures that we should expect to find much farther inland.

¹ Prepared by E. J. Saunders, of the University of Washington.

The interception of the moist ocean winds by the Cascade Mountains gives this area a very low annual precipitation, and the belt of which it is a part has been called the arid belt of the State. The air, moving from the west, loses much of its moisture in passing over the Cascades, and in descending on the east side is dynamically warmed so that it blows over the Columbia River basin as a dry wind, able to take up moisture rather than to cause any precipitation.



AVERAGE ANNUAL PRECIPITATION



FIG. 2.—Sketch map showing average annual precipitation.

It is not until it is forced to ascend the western slope of the mountains lying along the eastern boundary of the State that we have increased precipitation again.

PRECIPITATION.

The average annual precipitation for the stations in and about the section covered by the survey is given in figure 2. This shows

a slight variation from about 6 inches at Kennewick to 15 inches at Wilbur. The greater proportion of the area has less than 10 inches of rainfall annually. The maximum recorded for any year at Kennewick is 9.92 inches; at Sunnyside is 8.64 inches; at Ellensburg, 13.58 inches; and at Waterville, 18.65 inches. The minimum rainfall of any recorded year at Kennewick is 3.58 inches; at Sunnyside, 5.01 inches; at Ellensburg, 3.71 inches; at Waterville, 8.21 inches.

The very low precipitation here, as compared with 50 to 100 inches on the western slope of the Cascades, less than 100 miles west of this section, is accounted for by the fact that the air is cooled to such an extent by forced ascent in passing over the Cascade Mountains that the greater part of its moisture is deposited on the western slopes. In descending on the eastern slope it is dynamically warmed by increase of pressure at lower levels, and its capacity for moisture rapidly increases, thus favoring clear skies and scant precipitation. As a result of this change in humidity the annual rainfall gradually decreases as the air moves toward the Columbia River valley down the eastern slope and increases again as the air moves up the western slopes of the mountains toward the Washington-Idaho boundary. This area may therefore be said to lie in the rain shadow of the Cascades, and whatever precipitation is received must come as a result of cyclonic or convectional storms.

The monthly distribution of rainfall is shown in figure 3. While the division into a wet season from November to March, inclusive, and a dry season from April to October, inclusive, prevails and shows the effect of proximity to the western coast, the contrast between the two seasons is much less marked than in western Washington. The winter maximum is accounted for by the greater number and activity of the cyclonic or storm areas during the winter season, the movement of the warm moist air from the ocean over a colder continent and the fact that although deprived of most of its moisture in its passage over the Cascade Mountains, the air is cooled to a lower temperature in moving into the interior and thus yields additional precipitation. The dry season, or summer months, usually show a secondary maximum period, which occurs in May and June, these months in most of the stations having decidedly more precipitation than the preceding or following months, but not as much as the winter months. This is accounted for by the rather common heavy showers, thunderstorms, and even occasional cloud-bursts that occur following, or in the latter part of a severe hot spell which may have lasted several days or a week. These showers bring the average rainfall for the summer months up to a much higher proportion to the winter rainfall than it is for the stations on the western slope. This relation is characteristic of continental climate and east of the Rocky Mountains we find the summer rainfall

even greater than the winter rainfall. In this particular case, then, we have evidence of the two controls, the oceanic with a winter maximum and the continental with a summer maximum, the latter being yet more pronounced in its effects because of the proximity to the Pacific coast.

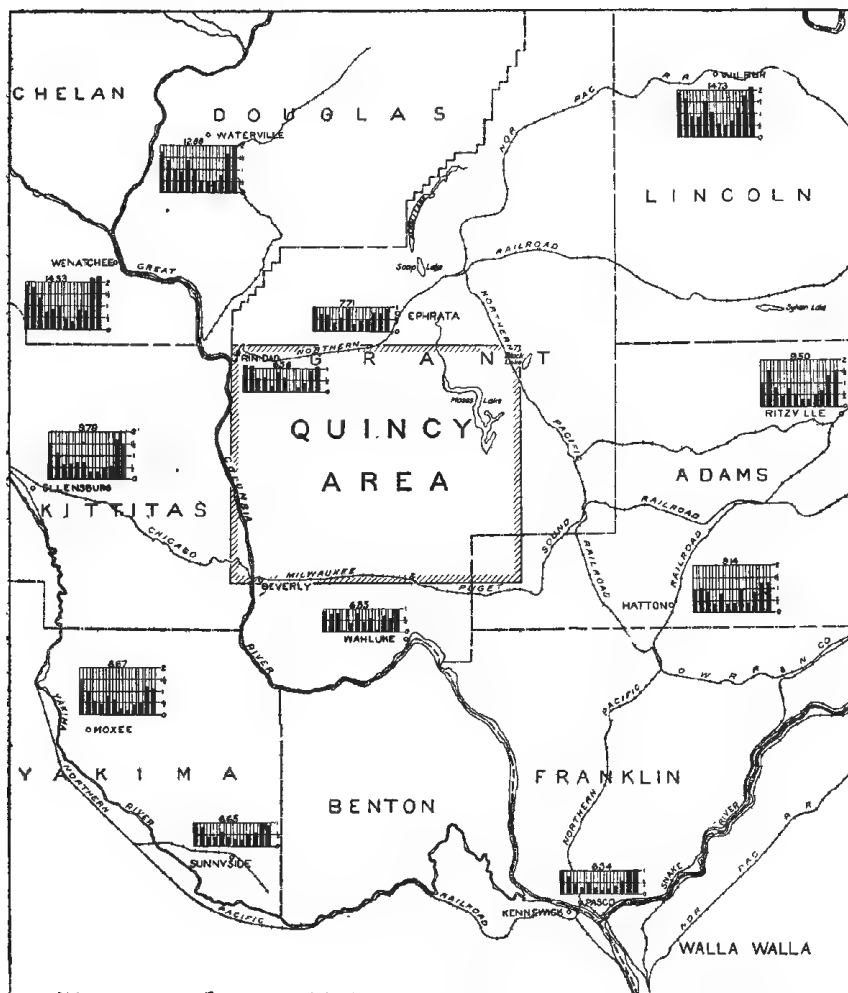


FIG. 3.—Diagram showing average monthly precipitation.

The average snowfall throughout the area varies from 8.2 inches at Sunnyside to over 60 inches at the higher or more northerly stations. The absolute annual maximum varies from 19.5 inches at Kennewick to 114.5 inches at Wenatchee, and the maximum snowfall for any year may be as low as 2 and 3 inches for some of the stations. The snow remains on the ground for several weeks at a time during

the cold spells, and frequently it will suddenly disappear as it is lapped up by the warm "Chinook" winds, coming down the eastern slopes of the Cascades, following the severe cold waves.

Coming in the winter months, at the time of the severe cold spells, it acts as a protective blanket and prevents the freezing of the roots of trees and plants. In melting it supplies moisture slowly enough to be absorbed and retained by the fine deep soil of portions of this area.

Another factor that is very important in the climate of this area, especially in the ripening and coloring of fruits, is the great number of clear days. The average year of this section will consist of about 195 clear days, 80 partly cloudy days, and 90 cloudy days, and of these only 50 days on which precipitation of more than 0.01 inch will occur. That means about 275 days each year during which there will be a considerable amount of sunshine.

TEMPERATURE.

The mean annual temperature for the area varies from 45° at Wilbur to 54° at Kennewick, thus showing about twice the variation shown in the whole section west of the Cascade Mountains. But it is in the study of the annual, monthly, and daily ranges that we see the most marked difference between this section and western Washington.

The range between the coldest and warmest month is 45°, or from 25° for January to 70° for July, as compared with 20° in western Washington, or from 40° in January to 60° in July. The average for the coldest month varies from 31.2° at Kennewick to 21.9° at Wilbur, and for the warmest month from 77.6° at Kennewick to 64.7° at Wilbur.

The records of the highest and lowest temperatures for different stations commonly shows an absolute annual range of 120° from -20° to 100°, and temperatures as high as 115° have been registered at Kennewick and as low as -30° at Waterville, but these extremes occur only during extended hot waves in the summer and cold waves in the winter, and on account of the low relative humidity of the air are not felt as they would be if the air were moist. During the warmest weather of the summer the evenings and nights are generally cool and pleasant, and during the coldest spells of winter the days are bright and clear.

The cold wave of the winter season is due to the extension of the high-pressure area with its low temperatures from the northeast over this region, and is usually accompanied by a slow drift of air from that direction. The warm waves of summer are also due to the presence of a high-pressure area to the east, causing the highly heated air from the interior to move westward over this region.

The daily range of temperature is much greater both in summer and in winter than in western Washington. This is shown for several dates and conditions by the thermograph curves for Ellensburg. (See fig. 4.)

The explanation of the strong annual, monthly, and daily variations of temperature is: First, the very slight moderating influence that the ocean winds exert here, on account of being intercepted by the Cascade Mountains; second, the fact that only the Rocky and Bitter Root Mountains protect this region from the low winter temperatures and the high summer temperatures of the continental interior; third, the air, having been deprived of most of its moisture in passing over the Cascade Mountains, is usually clear and allows

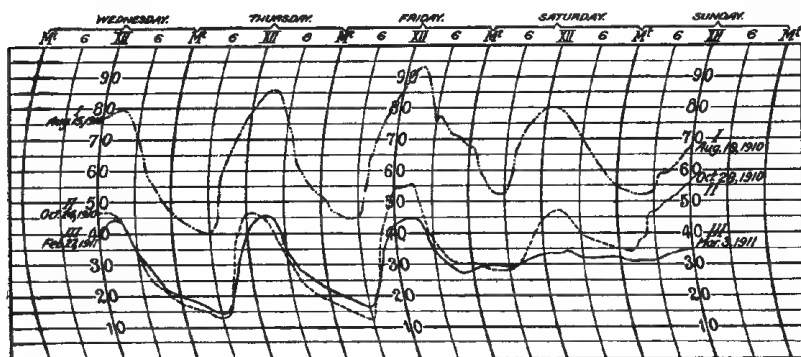


FIG. 4.—Sketch showing typical temperature curves.

much greater radiation of heat during the night and during the winter, thus increasing the daily and annual range of temperature.

KILLING FROSTS.

From the dates at which the earliest killing frosts in the fall and the latest killing frosts in the spring have occurred at the different stations, the average dates at which killing frosts may be expected are worked out in figures 5 and 6. The actual date of first or last frost being governed by the passage of well-developed anticyclonic areas will, of course, vary considerably from year to year, but the maps give approximately the dates between which frosts are apt to occur at any station.

In general the higher uplands are subject to frost earlier and later than the lower areas, but frequently the low flat valleys will have heavy frosts when the adjacent slopes and uplands are free from them, because of the drainage of the cold air down the slopes to the valleys, where the collection of cold stagnant air favors frost.

The earliest frosts in the fall will occur on the average between September 6 and October 21 in different parts of the area or, in

other words, frosts may be expected in some parts of the section any time after September 6, and in other parts of the section not before October 20. On the other hand, frosts have occurred as early as August 7 at Wilbur and Hatton, and August 23 at Ephrata, but not before September 25 at Kennewick and October 7 at Trinidad.

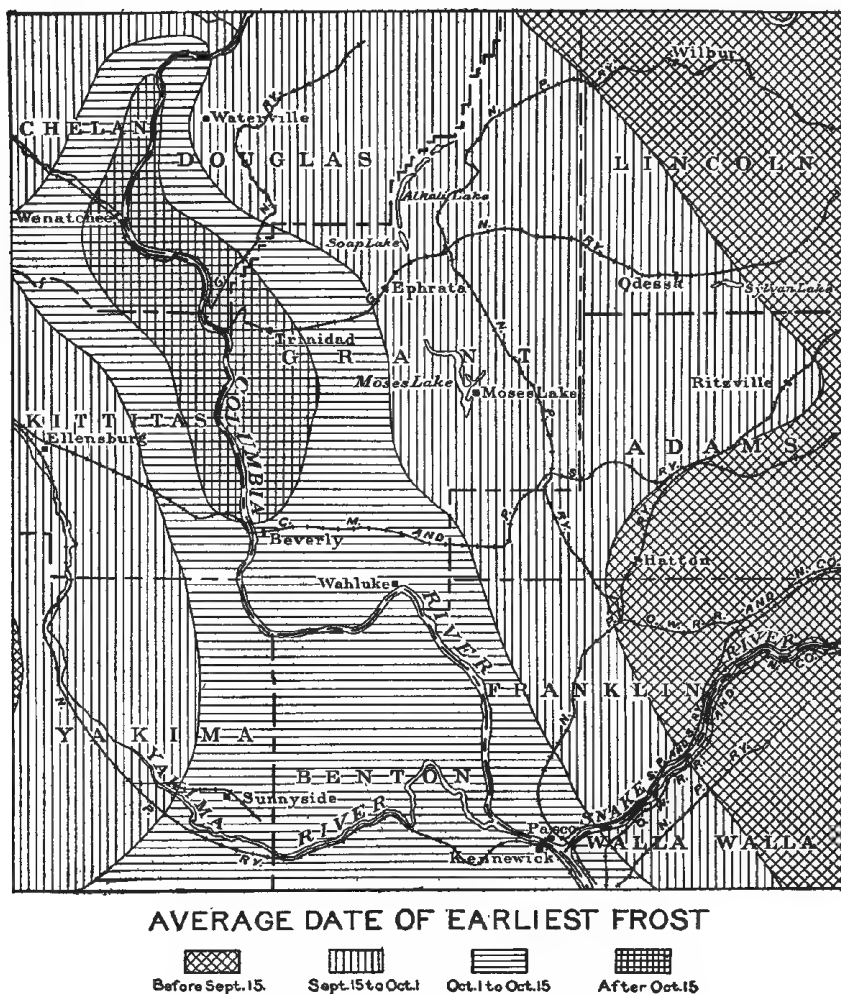


FIG. 5.—Sketch showing average date of earliest frosts in fall.

The average date of earliest frost in the spring is between April 5 and June 23, or frosts may be expected at Wilbur as late as June 23 and at Trinidad not later than April 5. Frosts have occurred at Wilbur as late as July 30, at Ephrata as late as May 15, at Odessa on June 3, at Kennewick as late as May 25, and at Trinidad as late as April 17.

WINDS.

Owing to topographic irregularities the prevailing direction of the winds varies considerably for different stations, but in general the winds are either west, northwest, or southwest, and occasionally only from an easterly direction, when they bring with them the cold waves of winter or the warm waves of summer.

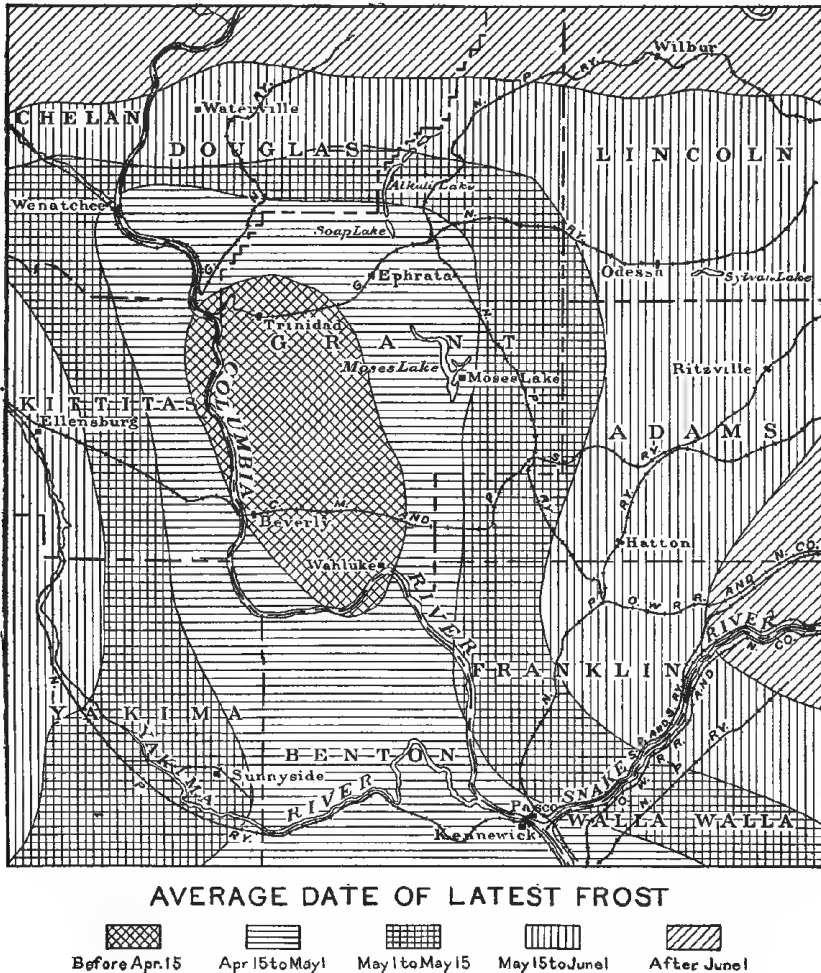


FIG. 6.—Sketch showing average date of latest frosts in spring.

During the fall and spring months strong and disagreeably cool, dry winds blow from the mountains over the plains to the east, the direction at different stations depending somewhat on local topography. The air seems to slide down the eastern slope of the mountains after several warm days and the winds will continue to blow for several days at a time, often attaining a velocity of 30 or

40 miles an hour. When these winds first begin, usually about noon or late in the afternoon, the temperature will fall 10° to 30° F. in a short time, and the first part of the blow often creates a regular dust storm. These winds are quite a relief after a few days of real hot weather which, in summer, they frequently follow.

During the winter months there is very little strong wind, but occasionally, following the passage of a cyclonic area to the east, the air moving into it from the southwest comes down the eastern slope of the Cascades and is warmed dynamically by increased pressure, due to its forced descent. Having lost most of its moisture as it passed over the mountains, it blows over the valleys east of the mountains as a warm, dry wind called the "chinook," often causing the sudden breaking up of a cold, stormy spell of weather and rapidly melting or licking up any snow or ice that may be present.

SUMMARY.

The climate of this section of the Columbia River Basin seems to be the result of a combination of oceanic, continental, and mountain climatic characteristics. The high temperatures of summer, the low temperatures of winter, and the summer maximum of rainfall in May and June, which is of immense importance to the wheat-growing sections of the country, are all interior characteristics. The winter maximum of rainfall, the fact that the summer warm waves and the winter cold waves are not as severe nor of as long duration as farther east is evidence of the oceanic influence. The clear, dry, exhilarating air and the strong mountain winds are the result of the situation on the east slope of the Cascade Mountains.

These conditions all combine to give the section one of the best agricultural climates on the continent, although the low rainfall makes irrigation necessary for the growing of most field crops and fruit.

AGRICULTURE.

The agricultural development of the Quincy area began in very recent years. Prior to the year 1900 the whole area surveyed was classed as a sandy desert and was inhabited only by a few ranchmen, who had located along Crab Creek, Moses Lake, or the Columbia River. The area was covered by a scrubby growth of sagebrush, but it also supported a good growth of "bunch grass," and the land was utilized exclusively as a range for horses and cattle.

During the last 10 years the land has been taken up rapidly, and although only a small percentage of the agricultural land is at present under cultivation, more or less development has taken place on every section open to settlement. The undeveloped sections consist mainly of nonagricultural land or of sections owned by the railroads which are not open to homesteaders.

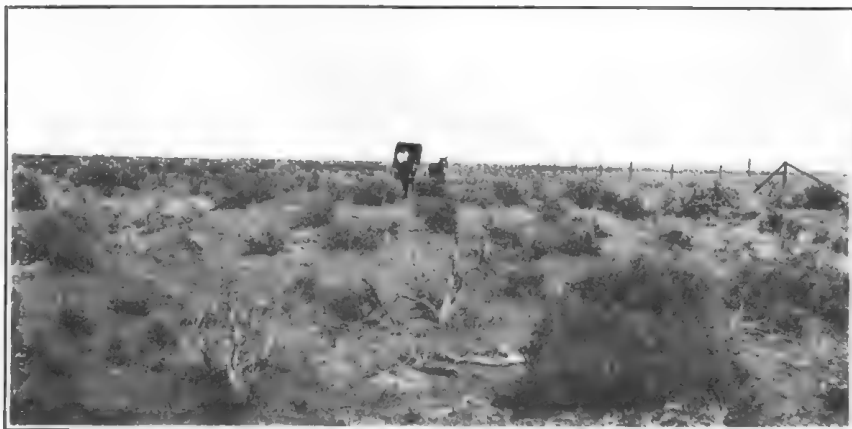


FIG. 1.—DESERT PLAIN IN QUINCY VALLEY, SHOWING NATIVE VEGETATION

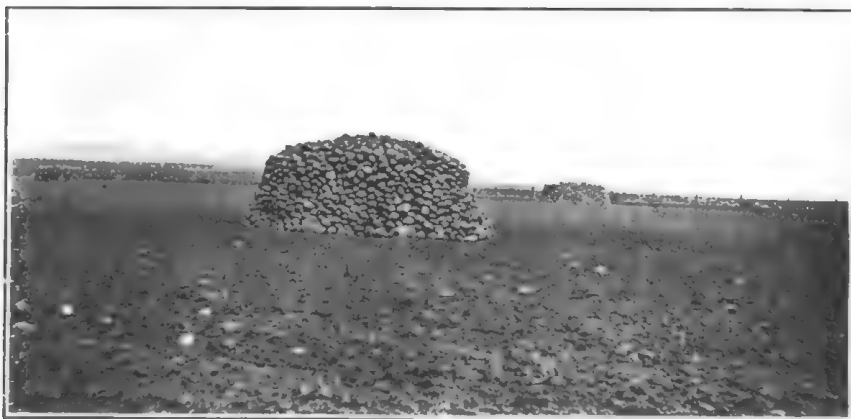


FIG. 2. —STONE CLEARED FROM SOILS OF EPHRATA SERIES.



FIG. 3.—DESERT PLAIN CLEARED AND PREPARED FOR PLANTING.

The cost of clearing the land of sagebrush (see Pl. I, fig. 1) is \$2 or \$3 an acre, and the total cost of clearing, breaking, and putting the land in condition for cultivation ranges from \$4 to \$6 an acre. In the case of some of the more stony types of soil the work of removing small bowlders which occur scattered over the surface is expensive (see Pl. I, fig. 1), and fitting the land for cultivation costs from \$10 to \$50 an acre (Pl. I, fig. 3).

Dry farming is practiced on the greater part of the cultivated land, and from the very beginning a large percentage of the total acreage has been utilized for growing wheat. Winter wheat is usually grown, though a small acreage is sowed to spring wheat. During the last few years the lack of rainfall during the spring and early summer months has caused the average yield of wheat to be very low, and a considerable acreage is now being cultivated to rye, as this crop seems to resist drought better than wheat.

Irrigation is practiced to a very limited extent in some parts of the area surveyed. Good yields of all crops are much more certain on irrigated than on unirrigated lands.

The growing of fruit under irrigation is rapidly becoming one of the most important industries in the area. All attempts to grow fruit without irrigation have failed, but where irrigation is practiced the young orchards are thriving. Most of the orchards in the area are not yet in bearing. Several small orchards in which the trees are from 3 to 6 years old are already producing profitable yields.

The wheat grown in the area has good milling qualities. When fair to good yields are obtained a large proportion of the crop is thrashed, and a considerable acreage is cut for hay and used in feeding the stock during the winter months. When the indications point to a small yield, the heads not filling well, owing to insufficient moisture, the entire crop is cut and utilized for feeding. The principal varieties of wheat grown are the Fife (winter wheat) and the Bluestem (spring wheat). During a season of average rainfall the yield of wheat ranges from 8 to 10 bushels per acre. Yields of 25 to 30 bushels per acre have been reported on a limited acreage in exceptionally favorable seasons. When droughts occur in the spring and summer months, however, the average yield is very low and in many cases the crop is a failure.

The rye grown in the area is used mainly for feeding. This crop seems to be very resistant to drought and a good stand is always obtained. When thrashed the yield is ordinarily only about 8 to 12 bushels per acre, as in many cases the heads do not fill properly. As in case of wheat, yields of 25 to 30 bushels per acre are reported in very favorable seasons.

Oats are grown to only a limited extent. Without irrigation this crop is usually a failure, but good yields have been obtained on limited acreages under irrigation.

Very little fruit is grown at the present time; but judging from the condition of the young orchards which have been set out in various parts of the area, both the soil and climatic conditions are well adapted to the growing of apples, pears, peaches, cherries, prunes, and apricots. The principal varieties of apples grown are the Jonathan, Stayman Winesap, Delicious, Rome Beauty, Spitzenberg, and Winesap. The Crawford and Elberta varieties of peaches are grown and produce well. The Bartlett and several other varieties of pears do exceedingly well. Cherries, apricots, and prunes produce large yields and the trees begin bearing at a very early age. A small acreage under irrigation has been cultivated to grapes. The Concord, Muscat, and Worden are the varieties grown, and although most of the vines are too young to bear they are in a flourishing condition.

Corn has been grown to a very limited extent and when thoroughly cultivated it has produced fair yields during favorable seasons. Without irrigation the crop is very uncertain and is frequently a failure.

Potatoes are produced for home use and for the local markets. Without irrigation the yield is uncertain, but the small acreage irrigated produces from 300 to 600 bushels per acre. The early varieties seem to give the best results.

Alfalfa is grown under irrigation in several parts of the area. An excellent stand is obtained and from 3 to 4 cuttings are usually obtained in a season. The yield varies from 5 to 7 tons per acre. An attempt has been made to grow alfalfa without irrigation, but while the stands are fairly good for the first year it is very doubtful if the crop will prove successful unless artificially watered.

Watermelons do well on almost every type of agricultural land in the area, but this crop has only been grown in small patches for home use and for the small local markets.

The agricultural development of the area is of such recent date that no system of crop rotation is in general use and the greater proportion of the cultivated land has been utilized exclusively for the growing of small grains. Summer fallowing is the general practice. As a result the fields are left bare and the loose surface soil is blown badly by the high winds that prevail in the region. Crops on adjoining fields are often seriously damaged by the drifting sand. On many of the sandy types of soil the failure to secure a profitable yield is due as much to drifting of the sand as it is to the lack of sufficient moisture. In some cases the soil is blown away from the roots of the plants, while in others the crop is covered by shallow

sand drifts. In these sandy soils the better results have often been secured by sowing the grain on stubble land. In this case the land is not plowed, but is gone over with a disk harrow, then sowed. The stubble prevents, in a measure, the drifting of the soil and a better stand is usually obtained.

A small acreage of wheat is sown in the spring, but, as a rule, the seeding is done in September or October. From 30 to 45 pounds of wheat are usually sown to the acre. If a rain follows the seeding there is always a better prospect for a good stand, but if the soil remains in a dry condition the wind either covers the seed with drifting sand or leaves it uncovered on the surface and a poor stand results. In view of the damage done by drifting soil trees to act as windbreaks should be planted along the fence rows.

Rye is sown in the fall. About 30 pounds of seed is used per acre, unless the field was in rye the previous year, when 15 to 20 pounds per acre is sufficient.

On the areas cultivated to fruit the trees are set out in rows from 22 to 30 feet apart. The first irrigation is given the orchards during the latter part of May, and the trees are thereafter watered about once a month during the summer. The soil is given a very thorough cultivation after each irrigation. The trees are usually sprayed with a solution of lime and sulphur just before they leaf.

Alfalfa is seeded with some cover crop during the late spring or early summer, 12 to 15 pounds of seed per acre being generally used. The crop is first irrigated during the latter part of May and about once a month during the summer. The date of the first irrigation and the frequency of the subsequent irrigations vary with the rainfall during the growing season.

Little or no fertilizer or manure is used on any of the soils in the area. It is commonly believed that the application of barnyard manure has no effect on the soils, but this is not true, as fields cultivated to grain have proved more productive after receiving an application of manure, although the effect was not noticeable until the third or fourth year following. This is probably due to the fact that it requires a considerable length of time for manure to decompose in so dry a climate.

A high class of farm labor can usually be secured without difficulty. When employed by the month \$35 and board is usually paid, and during the harvest season the prices paid for labor range from \$2 to \$3 a day.

The farms in the area are operated almost exclusively by their owners. A small area of land is leased from the railroads or large landowners. The farms vary in size from 160 acres, taken up as homesteads, to 320 acres, the allotment under desert claims. Some tracts which have been put under irrigation have been subdivided

into 10 or 20 acre farms. These are utilized for the growing of fruit or other special crops yielding large returns under intensive cultivation.

As a rule only a small part of the 160 or 320 acre tracts are in cultivation, but in some instances the entire farm is under the plow.

The value of undeveloped farming land varies from \$10 to \$100 an acre, according to the character of the soil and to its location with relation to the railroads and local markets. Highly improved land under irrigation and partly set out to fruit trees is valued at about \$400 an acre.

SOILS.

The materials from which the soils of the Quincy area are derived are of four kinds:

(1) The substructure of the whole region, extending downward from the surface in some localities and from a short distance below the surface over the greater part of the area, consists of successive sheets of black basalt lying approximately horizontally. Interbedded with these are occasional lenses of sand, silt, clay, or organic material supposed to have been deposited in lakes.

(2) Over the surface of the basalt lies a mantle of waterworn material, which varies considerably in thickness. It consists of well-rounded rock fragments of all sizes from silt and fine sand to boulders several feet in diameter. This mantle is thickest in the northeastern part of the area, and gradually thins out to the westward and along the northern base of the Frenchman Hills.

(3) Overlying the surface of both the basalt and the water-laid mantle is a mantle of wind-blown material, consisting mainly of fine sands. It occurs everywhere over the Beverly Valley, over the Frenchman Hills, and over the greater part of the Quincy Valley. South and southwest of Moses Lake the sand has accumulated in areas of typical sand dunes 60 feet or more in height. These dunes are at present moving eastward, invading the more hilly plains of the adjacent wheat-growing region. The northeastern part of the area is not covered with these drifting sands. In this locality the coarsest phase of the water-laid mantle of gravel and small boulders lies at the surface. A few shallow valleys, which traverse the eastern and extreme southern part of the area, have been cut out subsequently to deposition of these gravel deposits. The largest of these is the Crab Creek Valley. That part of the Crab Creek Valley which traverses the eastern part of the area is carved in the gravel mantle in places for a width of several miles. Its invasion by the sand dunes moving eastward along the northern foot of Frenchman Hills has obstructed drainage and caused the formation of Moses Lake.

(4) There is a narrow strip of recent alluvial material along the Columbia River and lower Crab Creek.

The soils of the area have been classified into 21 types, including Rough broken land and Meadow. The separation of these several soils is based principally on the texture of the surface soil and subsoil, but the origin, topography, and depth of the soil over the underlying rock have also been considered as important factors.

Small areas occur in almost every type, which differ in some respects from the soil as typically developed over large areas. These differences are usually due to the drifting of the sandy surface soil by the wind, causing the depth of the soil to vary considerably over areas of limited extent, to variations in the amount of bowlders or gravel in the surface soil or to slight differences in topography. In a more detailed survey some of the minor variations might warrant their separate mapping, but in this survey they are classed as phases of the soils with which they are associated, and when of sufficient extent are indicated on the map by means of distinctive rulings or by gravel symbols and are discussed separately.

On the basis of differences in geological origin and in general physiographic features the soils have been separated broadly into four groups.

(1) Those derived mainly from wind-laid deposits. The soils of this group fall under two subdivisions, as follows: (*a*) Soils derived from deposits of fine sand and silt that are underlain at a depth varying from approximately 6 feet to more than 30 feet by a massive formation of basaltic rock, which is usually separated from the subsoil by calcareous material; (*b*) Soils not underlain by calcareous deposits and derived from material which was probably first deposited by glacial floods, but has later been transported by winds and drifted into ridges and dunes, covering the underlying formations to a considerable depth.

(2) Soils derived from glacial material deposited by the flood waters along the course of an old glacial stream channel.

(3) Soils derived from recent alluvial deposits.

(4) Residual soils.

The first subdivision of group 1 comprises the soils of the Quincy series, which occupies a large proportion of the western, southern, and southeastern parts of the area surveyed. The material from which these soils are derived consists mainly of fine sand, very fine sand, and silt. Over the area occupied by the soils of the Quincy series, as typically developed, these deposits have an average depth of from 10 to more than 30 feet over the underlying rock. Over the areas occupied by the hardpan phases of the Quincy soils, however, the deposits are shallow and are underlain to a depth of from 15 inches to 6 feet by a more or less continuous calcareous deposit, which has the appearance

of a bed of limestone. The calcareous deposit usually rests on a mass of volcanic rock, which consists mainly of basalt. The origin of the deposits of fine material from which these soils are derived is uncertain. They probably represent the finer sediments deposited by glacial flood waters at the time the extensive areas of outwash gravel were laid down in the eastern part of the area. These deposits, however, have been modified to some extent by wind-blown material and the surface material of the lighter members consists essentially of such material. In the western part of the area small rounded boulders of basalt embedded in the underlying calcareous deposit occur in the deeper subsoils. In some localities the surface soils have been removed by the action of wind and the underlying calcareous deposit is encountered within a few inches of the surface, while on adjacent areas it is covered to a depth of many feet by fine drifting sands. When the underlying formations occur at a depth of 6 feet or more the deeper subsoils are hard, dry, and compact, but when the soils are shallow the subsoils are more porous and small fragments of limestone or small basaltic boulders are found scattered over the surface or mixed with the soil.

Where these deposits have a depth of 3 feet or more above the underlying rock the soils derived from them are amongst the most productive in the area, but when the rock is encountered at a shallower depth the soils are unable to retain sufficient moisture and the crops are likely to be injured by drought.

The rock outcrop phase of one of the types of the Quincy series differs widely from the typical soil in topography, character of substratum, depth, and in agricultural importance, and would in a more detailed survey warrant recognition as a distinct soil type. As it is of little agricultural importance, however, and as most of the soil material is probably of wind-laid origin, it is in this report considered as an unimportant phase of the type. Small areas of only a few acres in extent occur at frequent intervals, which could be used for agricultural purposes, though bedrock is always encountered at a depth of from 2 to 4 feet below the surface. A large percentage of the land, however, consists of extensive areas of rock outcrop, while boulders and angular fragments of basalt are scattered over the surface.

The second subdivision of group 1 comprises the Dunesand and the various types of wind-blown, drifting sands, classed under the head of the Winchester series. These sandy soils occur extensively in the central and east-central part of the area. Extensive areas of the Quincy fine sand, which is related to the soils of this subgroup in topography, appearance, and mode of formation, occur in the east-central, southern, and southwestern parts of the survey. The wind-blown sandy materials of this group of soils are derived from

several sources and the resulting soils differ considerably in texture, color, and mineral composition. The areas in the southwestern part of the survey and also the western border of the extensive areas in the central and east-central part have a light-gray to light-brown color. The surface often has the appearance of a coarse sand, as much of the finer material has been blown away, leaving a thin veneer of coarser material, consisting of coarse sand, small angular fragments of limestone, and scattered small gravels. The percentage of coarse material, however, in the main body of the drifting sand is small. In the southwestern part of the area the sand was probably first laid down along the valley of the Columbia River and has been drifted over the adjacent uplands to the east. The sand in this section of the area contains a large proportion of quartz and a very small admixture of the small particles of black basalt that form such a large percentage of the material composing the deposits in the eastern part. Along the western border of the large area of drifting sand in the east-central part of the survey the soil contains only a small amount of the black-sand particles, but to the east and southeast the quantity of black particles rapidly increases and becomes almost sufficient to cover the surface.

The sand composing the largest areas of Dunesand south and southwest of Moses Lake were probably first laid down by the glacial floods and later drifted into the mounds and ridges in which it now occurs. In the country south and east of Moses Lake these dunes and ridges vary from 25 to more than 60 feet in height.

The soils of group 2 contain large quantities of large and small boulders and waterworn gravel. In some localities this coarser material occurs both on the surface and mixed with the soil and subsoil, while in others the boulders are encountered mainly in the subsoil. A considerable proportion of the finer material composing the surface soils of this group is undoubtedly wind blown in origin, but the soils are derived mainly from material deposited by a glacial stream which formerly traversed the eastern part of the area. Geologists believe that the ice sheet which during the Glacial period moved southward through the Okanogan Valley finally filled the valley of the Columbia River, forcing the river southward through the broad channel now occupied by Crab Creek. During the period of melting ice a large volume of sediment-laden water flowed through this channel, forming the broad terraces on each side of the old valley and depositing the extensive beds of outwash material, consisting mainly of waterworn gravel. The material of this group gives rise to the soils of the Ephrata series.

The soils of group 3 are of small extent. They include the recent alluvial soils classed in the Beverly and the Red Rock series. The former occupy the strip of valley lands lying between the present

channel of the Columbia River and the foot of the steep bluffs, rising abruptly to the adjacent uplands. The soils are gray to light brown in color. These areas are essentially narrow, and in some places where the stream flows at the foot of the bluffs they are lacking. The larger bodies of alluvial land occur in the bends of the river and are often several square miles in extent. The material forming the soils consists mainly of sand, gravel, and small boulders derived from basaltic and quartz-bearing rock. The deeper subsoils are uniformly coarse in texture, consisting mainly of rounded cobbles and gravel laid down in the narrow valleys by earlier floods. The coarse material has generally been covered by deposits of fine gravel or sand. The finer material, though primarily deposited by the stream, has later been transported to some extent by the winds. The soils of the Red Rock series occur in the lower Crab Creek Valley. Here the sediments are of finer texture, consisting mainly of silt and clay, but the soils have been modified to a considerable extent by the addition of sandy material, which has been brought in by the wind. They are derived probably predominantly from basaltic material, and usually have a light-gray or drab color. With this group is also included the soils of the Naylor series and Meadow. The Naylor series is represented by a single inextensive type of alluvial material occupying local depressions and remnants of earlier glacial stream valleys. It is of gray to drab color, poorly drained, is derived mainly from basaltic material, has been subject to the addition of alluvial deposits and wind-laid material since its deposition, and is underlain often at shallow depths by a substratum of boulders or of bedrock.

The material mapped as Meadow consists of undifferentiated sedimentary material occupying poorly-drained portions of stream valleys or of recently exposed lake beds.

The fourth group includes residual soils or soils derived by weathering of the underlying rock in place. It comprises the Rough broken lands, which were either steep and mountainous or have such a rocky and uneven surface that they are of little or no agricultural value. The steep bluff bordering the lower valley of Crab Creek and the foothills of the mountains on the west side of the Columbia River consists principally of extensive outcrops of basalt. These rough and broken lands have been badly eroded, and the surface of the more level areas is intersected by many small canyons or deep gorges cut into the basaltic rock to a depth of many feet.

This group also includes the soils of the Cohasset series, represented in this area by but a single member. This is not at present utilized to any extent, but is of some potential agricultural value.

The soils over a large part of the area are well adapted to farming. The greater proportion of the land is very productive and with suf-

ficient moisture would produce very profitable yields. The sandy, fine sandy, and silt loams that have a depth of 6 feet or more are the better soils for dry farming. The surface soils of these types are compact and less subject to drifting than the lighter soils, while the deep, compact subsoils enable them to retain moisture better than the soils which are underlain at a depth of 2 to 3 feet by bedrock. Some of the types of light texture are cultivated with fair results. The continual shifting of the surface material reduces loss of moisture through evaporation, but the crops grown are usually injured to some extent by drifting soil, either by the blowing away of the soil from the roots or by the covering of the young plants by sand.

The areas of low hills and ridges of drifting sands and the area embraced by the larger sand dunes are utilized only to a limited extent as pasture land for stock. The gravelly and stony types of soil are not well adapted to dry farming, as the coarse porous character of the subsoils makes drainage excessive and prevents the storing of a sufficient supply of moisture. When irrigated, however, these soils are well adapted to fruit growing, and some of the most flourishing orchards in the area are located on them.

The following table gives the names and extent of the several types of soil encountered in the area:

Areas of different soils.

Soil.	Acres.	Per cent.	Soil.	Acres.	Per cent.
Quincy fine sandy loam: ¹			Rough broken land.....	14,556	2.0
Rock outcrop phase.....	82,944	19.5	Quincy silt loam.....	9,472	1.3
Hardpan phase.....	57,408		Red Rock clay.....	6,336	.9
Winchester coarse sand.....	87,232	12.1	Winchester fine sand.....	4,928	.7
Ephrata fine sandy loam.....	86,272	12.0	Cohasset silty sandy loam.....	4,416	.6
Quincy fine sand.....	42,944	12.0	Beverly fine sand.....	4,096	.6
Hardpan phase.....	43,072		Red Rock fine sandy loam.....	3,456	.5
Quincy silty fine sandy loam.....	62,976	8.8	Beverly sandy gravel.....	3,392	.5
Quincy very fine sand.....	56,512	7.9	Naylor silt loam.....	3,392	.5
Ephrata stony fine sandy loam....	46,336	6.4	Meadow.....	1,984	.3
Dunesand.....	39,680	5.5	Beverly gravelly fine sandy loam..	1,536	.2
Ephrata sandy loam.....	36,032	5.0			
Winchester sand.....	19,648	2.7	Total.....	718,720

¹ Mapped in two phases.

QUINCY FINE SAND.

The Quincy fine sand as typically developed is a grayish-brown to light yellowish-brown loose, incoherent fine sand. The soil to a depth of 3 or 4 inches, however, contains a considerable quantity of coarse sand. This is due to the superficial removal of much of the finer material by the wind. In some localities, usually where the underlying rock

is encountered at no great depth, small chips and angular fragments of an underlying hard calcareous material are found on the surface or mixed with the soil. The subsoil is usually similar to the soil in color and texture. As a whole, the texture of this type is not uniform and the percentage of coarse sand or fine sand in both the soil and subsoil often varies considerably over areas of limited extent. Deposits of coarse sand are sometimes found in the deeper subsoil.

The largest unbroken area of this soil as above described occurs in the west-central part of the survey, occupying the greater part of two townships. A second area of considerable extent is found covering the rolling uplands which border the valleys of lower Crab Creek and the Columbia River. The large area north of the Frenchman Hills borders on the east the western boundary of the Winchester coarse sand, and these soils have been mixed together to such an extent by drifting that no distinct boundary between them exists. As the area of Winchester coarse sand is approached the material forming the Quincy fine sand gradually becomes darker in color and the coarse particles of small, white, limestone fragments or coarse grains of white sand are gradually displaced by dark-colored particles of basalt.

The topography varies from undulating to quite rolling. Along the western edge of the larger area of the typical soil, which grades into the hardpan phase of the Quincy fine sandy loam, the sand ridges are low and rounded, but as the area of Winchester coarse sand is approached the dunes become higher and the topography is often rolling. In the southwestern part of the survey the sand has been drifted into a series of rounded hills and ridges or has been deposited along the slopes bordering the stream valleys.

The natural drainage as a whole is good. The constant shifting of the loose surface soil, forming a natural mulch, prevents excessive evaporation and the deeper soil and subsoil usually contain a considerable supply of moisture.

The material of the Quincy fine sand has been modified by winds transported and drifted into mounds and ridges and perhaps intermingled with wind-laid material from a foreign source. Over the greater proportion of the area occupied these deposits of wind-blown sand cover the underlying formations to a depth of many feet, but areas sometimes occur, especially along the boundary between the soil and the hardpan phase of the Quincy fine sandy loam where the underlying rock is encountered at a depth of from 5 to 10 feet below the surface.

The greater proportion of the Quincy fine sand is not at present used for farming. Some of the more level areas have been cultivated to wheat and rye and in seasons of average rainfall produced fair yields. The blowing of the soil away from the roots of the plants or the

covering of young wheat or rye frequently damages the crops more than does the lack of moisture. Extensive areas of this soil could be put under irrigation, but they would require leveling. A large quantity of water would be lost by seepage. The undeveloped areas support a scattering growth of sagebrush and bunch grass and are used to some extent as pasture land.

Quincy fine sand, hardpan phase.—The soil of the hardpan phase of the Quincy fine sand consists of 15 to 24 inches of light-gray to light grayish brown fine sand, containing a large quantity of small fragments of an underlying calcareous formation. The proportion of these and of coarse sand is greater in the immediate surface. This concentration is due to the fact that the finer material has been carried away by the wind and the coarser material has been left. The subsoil is a gray to very light brown sandy loam or fine sandy loam, containing a higher percentage of fine material and having a more compact structure than the soil. The subsoil rests upon a hard layer of calcareous material at an average depth of $2\frac{1}{2}$ to 5 feet. Frequently this underlying limy formation is encountered at a much shallower depth than this and there is little or no change in texture or structure throughout the entire soil section. The small limy fragments are always more abundant in areas where the calcareous layer lies at shallow depths. This type includes a few small areas of loamy sand which are more compact in structure and contain a higher percentage of fine material than the typical soil.

An extensive area of the hardpan phase of the Quincy fine sand, occupying the greater part of several townships, occurs in the southwestern part of the area. Several small bodies also occur in the southern and southeastern parts of the area. The surface of some of the more or less extensive upland plateaus is comparatively level, but the topography of the type as a whole is gently rolling. The natural drainage is good, but the nearness of the underlying calcareous formation and the porous character of the soil and subsoil give the type a low water retaining power.

This phase of the Quincy fine sand is of eolian origin, being derived from deposits of sand which have been transported by the wind and laid down over the gently rolling uplands. The deposits range in depth from 2 to more than 5 feet.

Only a small percentage of the area of this phase is under cultivation, the greater part still being covered by sage brush and bunch grass. Much of the undeveloped land supports a good growth of the latter and forms excellent pasture. A small acreage is in wheat and rye. In favorable seasons the yields range from 6 to 10 bushels per acre, but lack of moisture often causes the yields to be much smaller, and much of the crop is cut for hay. No irrigation is practiced, but with an abundant water supply the soil would be adapted to a wide range

of crops. The few wells in this phase of the type indicate that an adequate supply of water for irrigation can not be secured at a depth of less than 400 to 700 feet.

The following table gives the average results of mechanical analyses of samples of the typical soil and a single analysis of the soil and subsoil of the hardpan phase:

Mechanical analyses of Quincy fine sand.

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
Typical:		<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
550812, 550813.	Soil.....	0.6	1.6	3.4	58.6	30.7	3.1	2.3
Hardpan phase:								
550853.....do.....	3.3	11.1	10.2	26.1	33.6	11.7	3.9
550854.....	Subsoil.....	4.0	11.4	9.7	23.8	24.7	23.2	3.2

The following sample contained more than one-half of 1 per cent calcium carbonate (CaCO_3): No. 550854, 2.11 per cent.

QUINCY VERY FINE SAND.

The soil of the Quincy very fine sand, to a depth of 12 to 15 inches, consists of a gray to light grayish brown very fine sand, often of somewhat loamy character. There is a shallow surface covering of wind-blown sand, beneath which the soil becomes more compact in structure and contains a larger amount of silt. The subsoil, to a depth of 6 feet or more, is a gray to light grayish brown fine sandy loam. The deeper subsoil contains considerable silt, often approaching a silty fine sandy loam in texture.

An area of the type occupying the Frenchman Hills differs slightly from the general description just given. Here the topography is rolling, and on some of the steeper slopes the surface soil has been eroded away and small areas occur where only a shallow veneer occurs over the underlying calcareous substructure, gravels, and bedrock. In some of these shallow areas the underlying deposit of calcareous material occurs within a few feet of the surface, and small fragments of the rock are found in the soil and on the surface, giving the type many characteristics of the hardpan phase of the Quincy fine sandy loam. At the foot of some of the steeper slopes occur deep deposits of fine sand formed from the material washed from the hillsides and accumulating by drifting.

The topography of the greater part of this type consists of low, rounded elevations and ridges with broad comparatively level areas intervening. The surface of the area on the Frenchman Hills, however, is much more rolling than that of the type as a whole. The hills rise to an elevation of from 300 to 500 feet above the level of the adjacent plains and the slopes along the northern side of the

range are often steep. The natural drainage of the Quincy very fine sand is not excessive and the shallow deposit of drifting sand on the surface greatly reduces the loss of soil moisture through evaporation.

The soil of the Quincy very fine sand is derived from fine deposits probably first laid down by water, but subsequently modified by the action of wind. A large proportion of the material forming the surface soil and that which forms the soil on Frenchman Hills has certainly been transported and redeposited by the latter agency. No indications of alkali were found in either the soil or subsoil.

At present none of this type is irrigated, except a few small tracts used as gardens. The uncultivated areas support a growth of bunch grass and sagebrush, and are utilized for grazing. The cultivated lands are used almost exclusively for the growing of wheat and rye. The crops are frequently damaged by drought and the yields of grain are low. In seasons of average rainfall yields range from 8 to 10 bushels per acre. The entire area occupied by this soil, with the exception of that occurring on the Frenchman Hills, is well suited for irrigation, and with an adequate water supply it should be well adapted to small fruits, alfalfa, and general farm crops.

The following table gives the average results of mechanical analyses of samples of the soil and subsoil of the Quincy very fine sand:

Mechanical analyses of Quincy very fine sand.

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
550814, 550816.....	Soil.....	0.3	0.9	2.8	32.3	49.9	10.1	3.2
550815, 550817.....	Subsoil.....	1.9	2.2	2.0	18.6	34.8	35.4	5.1

QUINCY FINE SANDY LOAM.

The Quincy fine sandy loam member of the Quincy series is not typically developed in the area included within this survey. Two phases of the type, however, occur extensively, one of which is of considerable agricultural importance. The two phases differ widely from each other and from the typical soils of the Quincy series. They are indicated upon the soil map by appropriate rulings, explained in the map legend, and will be individually described.

Quincy fine sandy loam, hardpan phase.—The soil of the Quincy fine sandy loam, hardpan phase, consists of a fine sandy loam of light-gray to light grayish brown color. Small fragments of the hard, calcareous formation which underlies the type are usually found on the surface and mixed with the soil. In some localities a few rounded basaltic boulders are found on the surface, but neither

the boulders or fragments of limestone are numerous enough over the greater proportion of the type to influence the texture of the soil to any extent.

The subsoil consists of a compact fine sandy loam which is slightly lighter in color than the surface soil. At depths ranging from 20 to 36 inches occurs the calcareous formation referred to above and small fragments of this material are found throughout the subsoil. In some localities small rounded boulders of basalt are also present in the deeper subsoil embedded in the calcareous formation.

A shallow deposit of wind-blown sand is often found over the areas of this type. This drifts into low mounds and ridges, causing the depth of the soil to vary considerably even within small areas. Just beneath these shallow drifts of wind-blown sand the entire section of soil down to the underlying rock has a very compact structure.

Small areas occur at intervals throughout this type where a large amount of small fragments from the underlying calcareous formation are found scattered over the surface and mixed with the soil. These areas, however, are seldom more than a few square rods in extent. They occur at intervals over sections where the underlying rock is very near the surface. The fine material has been blown away leaving the small fragments of rock, which are too heavy to be moved by the winds. Along the western boundary of the larger area of the hardpan phase of the Quincy fine sandy loam, in T. 19 N., R. 23 E., the underlying rock is very near the surface and on some of the low knolls and ridges small fragments of the underlying calcareous formation are turned up with the plow. In this locality the soil is lighter in color and contains a larger percentage of silt, often having the characteristics of a silty fine sandy loam. The lighter color and higher silt content of this phase is due to the material derived from the weathering of the calcareous formation beneath.

A sandy phase of this type occurs in sections 3, 4, and 5, T. 18 N., R. 23 E., where the wind has drifted the loose surface soil into low mounds, sometimes covering the compact soil to a depth of several feet. The larger area of the hardpan phase of the Quincy fine sandy loam lies in the western part of the area surveyed and north of the Frenchman Hills. Several other less extensive bodies occur along the lower slopes south of Frenchman Hills and on the gently rolling uplands in the southeastern part of the area.

The surface of the larger area has the general appearance of being almost level, but the low, rounded elevations and broad, shallow depressions give it as a whole a gently undulating topography. The topography of the areas which occur south of the Frenchman Hills is slightly more rolling than that of the larger area, lying north of this range.

The soil has good natural drainage, but the nearness of the underlying substratum makes it difficult for the subsoil to hold much moisture and the crops grown frequently suffer from drought. The soil is derived from wind-blown deposits of fine sand, very fine sand, and silt. A part of this material may represent the finer sediments of the water-laid mantle that covers the surface of the eastern part of the area, but the surface soil is predominantly wind-blown in origin. No harmful accumulations of alkali were found in either the soil or subsoil of this type.

The areas under cultivation are used exclusively for the growing of wheat and rye. In seasons of average rainfall yields of 8 to 10 bushels of wheat and 10 to 15 bushels of rye per acre are secured. A large proportion of the rye crop is not thrashed but made into hay. When a poor stand of wheat is obtained or when the yield of grain promises to be very small this crop is also used for hay. None of this soil is at present under irrigation, although a very large proportion of it is well adapted to irrigation farming. With a sufficient supply of water the soil should produce very profitable yields of all crops grown in the area.

Quincy fine sandy loam, rock outcrop phase.—The soil of the Quincy fine sandy loam, rock outcrop phase, is prevailingly a light yellowish brown fine sandy loam. It may include, however, undifferentiated areas of soil of variable texture, but usually a sandy loam, silt loam, or loam. The areas of soil are interspersed with numerous and comparatively extensive areas of rock outcrop or of fragmental basaltic rock.

The soil is believed to be predominantly of wind-blown origin and has been drifted to some extent, but the underlying bedrock is always encountered not far below the surface. A large area of this type occupies a broad bench along the northern side of the lower Crab Creek Valley, while another extensive area occurs in the extreme southeastern corner of the survey. Several smaller areas are also found along the Crab Creek Valley and along the bluffs bordering the Columbia Valley.

The topography is very broken. Small comparatively level benches or plateaus occur, but they are intersected by deep, canyon-like erosions, cut into the underlying rock, while pyramids or flat-topped elevations rise abruptly at frequent intervals. This type of topography owes its origin to the erosive action of the flood waters of an old glacial stream. During the Glacial period the broad valley which traverses the eastern and southern parts of the area was occupied by the Columbia River and also served as an outlet for the waters of the melting ice. The larger areas occupied by the rock outcrop phase of the Quincy fine sandy loam formed part of the channel of this glacial stream. The material overlying the hard basaltic rock

was eroded away, and large boulders and rock fragments were laid down along the valley. The small bodies of surface soil owe their origin to material which has been deposited by the winds. The small areas in the western part of the survey have also been found by the removal of the material originally overlying the basaltic rock and subsequent eolian deposition.

The phase is of little or no agricultural value. One small area has been irrigated and set in fruit trees, but the soil is so shallow that it is doubtful if fruit growing will prove successful. The sandy soil supports a sparse growth of bunch grass and sagebrush and the land is utilized to some extent for grazing.

The following table gives the average results of mechanical analyses of samples of the soil and subsoil of the hardpan phase of the Quincy fine sandy loam:

Mechanical analyses of Quincy fine sandy loam, hardpan phase.

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
550807, 550810.....	Soil.....	1.2	1.9	2.3	17.6	39.9	32.1	4.9
550808, 550811.....	Subsoil.....	4.2	4.4	3.1	18.3	33.7	30.3	5.9

The following sample contained more than one-half of 1 per cent calcium carbonate (CaCO_3): No. 550808, 0.61 per cent.

QUINCY SILTY FINE SANDY LOAM.

The Quincy silty fine sandy loam, to a depth of 15 to 24 inches, consists of a yellowish-brown or grayish-brown fine sandy loam, carrying a relatively high percentage of silt. When wet the soil is considerably darker in color than when dry. It has a tendency to bake and crack in drying out after rains, yet when plowed or cultivated it breaks up very readily into a mellow seed bed. On the slopes and sometimes on the ridges small angular fragments of limestone are of frequent occurrence. Under favorable conditions the surface material is easily shifted by the winds, and at times the surface has the appearance of a lighter and coarser textured soil. This is especially the case where summer fallowing is practiced, the winds removing much of the fine material, leaving a thin coating of a rather coarse black sand and small quantities of gravel, while adjoining areas are covered to a depth of a foot or more with drifts of a fine or very fine sand.

The subsoil is a compact grayish silt loam which rests upon a calcareous formation at a depth of 4 to 10 feet or more. Occasionally the silty subsoil is absent and the soil continues with little or no change until bedrock is encountered 5 feet or more below the surface. Both soil and subsoil contain noticeable quantities of fine particles of mica.

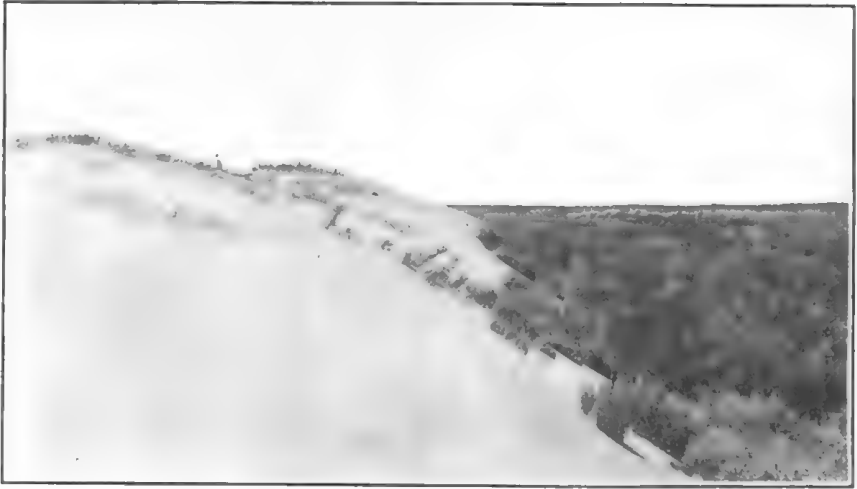


FIG. 1.—DUNE SAND ENCROACHING ON DESERT PLAIN SOUTH OF MOSES LAKE.



FIG. 2.—ORCHARD NEAR MOSES LAKE.
[These trees have been grown under irrigation.]



FIG. 1.—VINEYARD AND ORCHARD ON SOILS OF EPHRATA SERIES ON MOSES LAKE
[Irrigation is necessary for grapes as well as orchard fruits in this area.]



FIG. 2.—BASALTIC ROCK CLIFF ALONG VALLEY OF CRAB CREEK SOUTH OF MOSES LAKE.

The Quincy silty fine sandy loam forms an area 3 to 4 miles wide, south of the Frenchman Hills, extending from the west side of T. 16 N., R. 25 E., to the large area of the rock outcrop phase of the Quincy fine sandy loam along Crab Creek. An extensive area also occurs in the northwestern part of the survey, and a single small area upon the Frenchman Hills.

The topography is in general level to rolling. Many comparatively level areas occur, but these are often dissected by deep V-shaped draws which mark drainage channels. These, however, seldom carry any water, except after heavy rains.

The Quincy silty fine sandy loam is derived from deposits of fine sand and silt, principally wind blown in origin. Only a small percentage of the area lying south of the Frenchman Hills is under cultivation, the greater proportion being covered with a heavy growth of sagebrush and some bunch grass. A larger proportion of the area occurring in the northwestern part of the region surveyed is under cultivation.

The cultivated areas are devoted almost entirely to the production of wheat and rye. In especially favorable seasons wheat yields from 8 to 10 bushels per acre and rye about the same. In many seasons, however, the yields are hardly sufficient to pay for harvesting. When the indications are that the crop will not fill properly both wheat and rye are cut for hay. Small patches of potatoes and corn are occasionally grown, but as a rule the yields are very light. Under present conditions it is doubtful if the yields are sufficient to justify any attempt at cultivation, but if water for irrigation is secured, this would doubtless prove one of the most productive soils in the area. Water for domestic use is obtained at an average depth of 200 to 350 feet, but the supply does not seem to be sufficient to justify the sinking of large wells for irrigation purposes.

Land of this type is valued at \$20 to \$50 an acre.

The following table gives the average results of mechanical analyses of samples of the soil and subsoil of this type:

Mechanical analyses of Quincy silty fine sandy loam.

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
550803, 550805, 550824.....	Soil.....	<i>Per cent.</i> 0.9	<i>Per cent.</i> 1.1	<i>Per cent.</i> 1.8	<i>Per cent.</i> 14.9	<i>Per cent.</i> 32.9	<i>Per cent.</i> 43.6	<i>Per cent.</i> 4.7
550804, 550806, 550825.....	Subsoil.....	.3	.7	1.7	11.0	29.1	52.3	4.9

The following sample contained more than one-half of 1 per cent calcium carbonate (CaCO_3): No. 550825, 3.13 per cent.

QUINCY SILT LOAM.

The soil of the Quincy silt loam consists of about 10 inches of light yellowish brown to light-gray silt loam, relatively high in very fine sand. The surface is compact, and when in a dry condition the uncultivated areas have the appearance of being baked and slightly sun cracked. The clay content of the soil is not sufficient to make it sticky or tenacious when wet, but there is enough fine material present to cause it to break up into small compact clods, and the surface of even freshly cultivated areas is sufficiently compact to prevent the soil drifting. The subsoil to a depth of 6 feet or more is a gray to light yellowish brown silty material very similar to the surface soil in texture, but containing less organic matter and being slightly lighter colored. The subsoil is very compact in structure, has a depth of 6 to 30 feet, and rests upon bedrock.

The soil occurs in one unbroken area in the northwestern part of the survey comprising approximately 14 square miles. It occupies a broad, shallow depression lying between a low ridge on the south and the lower slopes of the range of rolling hills which extends outside the area included within the survey from a point just west of Quincy to a point near the town of Winchester on the north. The surface of this area has the general appearance of being level, but there is a gentle slope on each side toward the center of the basin. An occasional gentle swell or shallow depression gives to the type as a whole a very gently undulating topography.

Under the existing climatic conditions and present methods of farming the natural drainage of this soil is sufficient. The rainfall is light, and as dry farming is practiced on the greater proportion of the type the retention of moisture rather than its removal is of the greatest importance. The level or basinlike topography prevents rapid run-off and the compact subsoil retains moisture better than the types underlain by coarse, porous material. If, however, irrigation is extensively practiced on this soil or on the surrounding areas which occupy a higher elevation a more thorough system of drainage would be necessary on many of the areas occupying the shallow depressions. These depressions would receive the seepage and drainage waters from the surrounding land, and without thorough drainage harmful amounts of alkali would accumulate in the soil.

The Quincy silt loam consists probably of wind-laid material derived principally from the finer sediments probably deposited by water during the same period in which the extensive gravel deposits were laid down in the northeastern part of the area. The former sediments consist mainly of very fine sand and silt. Some material washed in from the slopes of the adjacent hills has also entered into the composition of this soil. Small spots seldom more than a few

square rods in extent on which the young wheat or rye becomes yellow and wilted occur occasionally on areas of this soil. This condition of grain crops is generally supposed to be due to alkali, but analyses of the upper 6 feet of soil failed to show the presence of more than a trace of harmful salts.

When well cultivated and when sufficient moisture is available the soil is very productive, and its power of retaining moisture makes it well adapted to dry farming. The entire area of this type is well adapted to irrigation. These facts, together with the location of this body of soil in relation to the railroad and principal local markets, have caused more of it to be developed agriculturally than of any other type in the area.

Where dry farming is practiced wheat and rye are the principal crops. Small tracts are planted in potatoes and vegetables for home use, but the yields are usually uncertain. Oats have been grown to a limited extent. This crop has not proved profitable, as it does not withstand droughts well. In seasons of average rainfall the yield of wheat is 8 or 10 bushels per acre and in very favorable seasons as high as 20 to 25 bushels per acre. The rye grown is used mainly in the form of hay. When thrashed the yield is estimated to be from 8 to 15 bushels per acre. Much larger yields may be obtained when the rainfall is unusually heavy. The small acreage of this soil irrigated produces very profitable yields of all the crops grown. Fruit trees do well, and the acreage in orchard is rapidly increasing. When irrigated, potatoes, melons, and other vegetables produce large yields. Oats and alfalfa have been grown successfully on irrigated land.

The following table gives the results of mechanical analyses of samples of the soil and subsoil of the Quincy silt loam:

Mechanical analyses of Quincy silt loam.

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
550857.....	Soil.....	0.0	0.5	1.3	9.3	32.6	51.8	4.4
550858.....	Subsoil.....	.0	.5	1.0	6.3	27.5	59.6	4.9

WINCHESTER COARSE SAND.

The soil of the Winchester coarse sand consists of a dark-colored or nearly black sand carrying large quantities of coarse sand and a small amount of fine gravel. The dark-colored grains are rounded and subangular fragments of basalt and the light-colored grains are chiefly fragments of quartz and feldspar. The soil also carries small

quantities of mica. In general, the basalt fragments comprise the greater proportion of the coarse particles of the soil, while the finer material consists of nearly equal amounts of dark and light colored sand grains. In portions of the type a few rounded basalt gravels occur both on the surface and in the first few inches of the soil. Though there are slight variations in the texture of the immediate surface, due to the sorting of the material by the wind, the texture of the soil is usually uniform to a depth of 6 feet or more. The surface is loose and porous and the whole soil section is only slightly more compact. Over a large part of the type the sand is many feet in depth. In the lower Hiawatha Valley the sand is underlain by boulders at depths varying from 15 to 25 feet.

The type occupies a continuous area near the central part of the survey. Beginning near the western side of R. 25 E., a few miles south of Winchester, it extends southward to the foot of Frenchman Hills and eastward, on each side of the area of Dunesand to Moses Lake and Crab Creek. Three small areas occur in T. 16 N., R. 25 E., T. 16 N., R. 26 E., and T. 19 N., R. 26 E.

The present topographic features are due to wind action. They consist of low ridges nearly parallel and rounded mounds surrounding lower, irregular nearly flat areas. Portions of the type adjacent to the Dunesand have a more rolling topography, but are distinguished from it by the presence of vegetation. The type is well drained and free from alkali.

The Winchester coarse sand is composed of fragments which were held in suspension by the water of a glacial stream and were deposited on the western and southern portions of the large outwash plain of this stream, probably at the time when its waters were checked by the Frenchman Hills and while the stream was cutting its way across this ridge. On account of the arid conditions existing since the withdrawal of the glacial waters the material has been so drifted and modified by wind action that all traces of deposition by water have been obliterated to a depth of several feet. The boundary of this type has doubtless been extended until it now covers considerable areas of what was originally Ephrata sandy loam and Ephrata fine sandy loam.

At present the greater part of the type supports a growth of black and other varieties of sagebrush, rabbit brush, chaparral, bunch, and spear grass. Many varieties of sand-loving plants flourish in their season. In general the part of the type north of the Dunesand supports a thicker growth of vegetation than the portion south and represents that part of the type first taken by vegetation which has now attained a sufficient growth to prevent the further drifting of the sand.

The type is quite retentive of moisture, as moist soil is usually encountered at a few inches below the surface. This fact is probably due to its great moisture storing capacity and to the constant shifting of the surface particles which forms a shallow mulch and thus decreases the loss by evaporation.

Comparatively little of the type is cleared and under cultivation. Rye makes a good growth of straw but gives small yields of grain. Corn does well in favorable seasons. Melons of excellent quality and potatoes give good yields. The bunch and spear grass afford good pasturage for horses and cattle.

During an average season the soil seems to have sufficient moisture to grow crops, but the difficulty arises from the inability to secure a good stand. When a field is cleared of its native vegetation the loose and incompact nature of the soil permits the spring winds either to blow the seed out of the ground or to drift fresh sand over the growing crop to such an extent that reseeding is necessary, in which case a repetition of the above results is quite probable. In some cases the wind-blown sand so cuts and tears the tender plants as to destroy all prospects of a crop. This trouble will become less and less as the country is settled and planted to permanent crops.

Cottonwoods grow rapidly, with a little attention, and should be planted along the roads and fences for windbreaks. In clearing fields for planting the work should be begun on the western side of the section, so that the sand will not drift over portions of the field already planted. Late spring plowing is recommended. Rye stubble land should be disked or harrowed and seeded without plowing.

The type requires considerable leveling before it can be irrigated, as the loose soil would wash too readily to permit the use of the furrow system of irrigation, except on very gentle slopes. The check system should be used for irrigating alfalfa. Under irrigation this soil is adapted to a variety of crops, chiefly alfalfa, melons, potatoes, truck crops, and certain varieties of fruit.

Very little of the land of this type is on the market, and there is no demand for it at present, owing to the uncertainty of yields and its distance from market.

The following table gives the average results of mechanical analyses of samples of the soil of Winchester coarse sand:

Mechanical analyses of Winchester coarse sand.

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
550821, 550838.....	Soil.....	2.4	27.0	24.8	31.3	7.9	4.1	2.3

WINCHESTER SAND.

The Winchester sand is a medium brown to dark-brown sand of medium to rather fine texture and of loamy character, with a depth of 3 feet, usually underlain by many feet of dark-colored sand. Underneath a thin mantle of loose sand, which covers the surface of a large proportion of the type, the soil is loamy and compact to a depth of about 2 feet. Below this depth the texture is practically the same as that of the soil, but the compact structure is lacking. Although the bulk of the soil material is the same in the two soils, the higher percentage of fine material, which imparts the characteristic brown color and compact structure to the Winchester sand, distinguishes it from the Winchester coarse sand. The difference between these two soils when typically developed is readily noted, but the change from one to the other is so gradual that the boundary between them is arbitrary. Small areas of Winchester coarse sand occur within the sand.

Only two areas of the type were mapped in the survey, one lying about 3 miles south of Winchester, the other about 3 miles south of Morrison.

The topography of the Winchester sand is undulating and consists of low, broad mounds and ridges, with nearly level areas of varying size between them. The type has good underground drainage and is free from alkali.

The material as originally laid down was the same as that of the Winchester coarse sand. It has been modified by the addition of fine material blown from the soil types to the north and west. As all traces of water action have been obliterated by the wind, the type is now classed as an eolian soil.

The native vegetation consists of sagebrush, rabbit bush, bunch grass, and spear grass. Small flowering plants are common on uncleared areas. The vegetation is sufficient to prevent drifting by the wind, but on cleared fields under cultivation the wind drifts the soil to a considerable extent.

As a rule it is deeper to moist soil in this type than in the Winchester coarse sand, as there is a greater loss by evaporation, owing to the more compact structure of the soil.

Though a considerable part of the type is cleared and broken, only a small percentage is now under cultivation. Rye is grown chiefly for hay. Potatoes, melons, and other truck crops do well. Good yields of corn are reported in favorable seasons. Uncleared portions of the type afford excellent pasturage. A plentiful supply of water is found at depths varying from 25 to 175 feet. Like the Winchester coarse sand, the securing of profitable yields depends largely upon the effects of the wind which prevails during the spring and the

early growing season. Careful attention should be given to the best methods and the time for preparing the land for planting, which will decrease the liability of loss by the wind. All stubble and other trash should be left on the surface for protection. Late plowing is advised. Systematic planting of windbreaks should be practiced.

Some leveling is necessary before any large area of this type can be irrigated. The cost of this is comparatively small. The rather compact nature of the soil, its ease of cultivation, good drainage, and the low cost of preparing the land make the type a desirable one for farming under irrigation. When the type is irrigated it is adapted to alfalfa, melons, potatoes, other truck crops, berries, apples, and certain other varieties of fruit.

A wide variation in value is placed upon the type, and these values are constantly changing. No recent sales are reported.

The following table gives the average results of mechanical analyses of samples of the soil of this type:

Mechanical analyses of Winchester sand.

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
550836, 550837.....	Soil.....	3.8	17.1	24.3	35.7	11.1	5.6	2.2

WINCHESTER FINE SAND.

The soil of the Winchester fine sand, to a depth of 3 feet or more, consists of a very dark gray fine sand containing a relatively large proportion of medium and some coarse sand. The surface is often covered with a thin coating of a medium to coarse black sand, while much of the finer material is a brownish color. A phase of the type occupies a small part of secs. 7 and 18, T. 17 N., R. 26 E. Here the sand is underlain at comparatively shallow depths by a compact alkali subsoil.

Only one body of Winchester fine sand was mapped in the area. This occurs as a long, narrow strip along the base of the north slope of the Frenchman Hills and contains several square miles. In general, the whole type occupies a stretch of country where the surface consists of a series of low wind-blown ridges and mounds with corresponding depressions between them, thus giving the type an irregular topography. Because of the loose, porous nature the drainage of the type is excessive.

The Winchester fine sand is derived from sedimentary material deposited on the glacial outwash plain. This has later been modified by the addition of fine brown wind-blown material. The type is classed as an eolian soil, as it owes its present formation to wind

action, which has destroyed all evidences of deposition by water to a depth of several feet.

The Winchester fine sand supports a rather scant growth of sage-brush, bunch grass, and other desert plants. Only a small percentage is under cultivation.

Rye and wheat are practically the only crops grown, and as a rule the yields are very light. When the vegetation has been removed the loose and incoherent nature of the type permits the wind to blow and drift the soil so as to make it very difficult to secure a good stand of crops. After the surface has been leveled and an abundance of water secured for irrigation the type should be well adapted to alfalfa, certain varieties of fruit, and truck crops.

Below are given the average results of mechanical analyses of typical samples of the soil:

Mechanical analyses of Winchester fine sand.

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
550822, 550823.....	Soil.....	0.2	5.5	20.6	50.1	17.9	3.7	1.8

DUNESAND.

The Dunesand consists of a dark-colored grayish brown drifting sand, differing from the Winchester coarse sand in the absence of coarse material and of vegetation and in topography and sometimes in color. Areas of the Winchester coarse sand too small to be shown in the map occur within the type. With the exception of the immediate surface of the windward side of the dunes, which is often firm enough to support a person's weight, the Dunesand is always loose and incoherent.

The type occupies a large area, from 1 mile to 5 miles wide, in the east-central part of the survey and extends from the west side of Range 26 east to the eastern limits of the survey. A few other small areas occur in this vicinity.

A large percentage of the dunes are crescentic or consist of small crescentic dunes joined together so as to form a long continuous ridge. Between these dunes are long narrow troughs, which often extend nearly across the type. These dunes vary in height from 20 to more than 60 feet.

In certain parts of the area covered by the type occur what are locally known as "potholes." These consist of shallow elliptical basins, from 1 acre to more than 100 acres in extent. In the northern part of many of these basins small ponds occur, which have the steep lee side of the dunes on the west and narrow strip of meadow on the

east. The presence of these ponds in the desert is due to the fact that the water table is very shallow in the locality and that it comes to the surface in many of these depressions. The water is slightly alkaline on account of the constant loss by evaporation, and the surrounding meadow is covered by a thick growth of salt grass and by alkali crusts. The water level of these ponds is practically stationary. Tules, cattails, and other water-loving plants grow in the ponds, and willows are common on the lee side of the dunes adjacent to the ponds.

The area occupied by the Dunesand is a portion of the glacial outwash plain and is correlative with the part occupied by the Winchester coarse sand. The drifting of the sand has prevented the growth of vegetation and destroyed all evidences of water deposition. Vegetation is gradually encroaching on the Dunesand area. Plate II, fig. 1 shows a large dune with vegetation just getting a foothold. Within the memory of the earliest settlers a part of what is now covered with vegetation and mapped as Winchester coarse sand was drifting sand. Since the withdrawal of the glacial waters the sand has drifted into and almost obliterated the old glacial stream channel, thus damming Crab Creek and forming Moses Lake. When the water of Moses Lake reached a level a few feet higher than the present one it made a new channel across the Dunesand. This channel is now dry, as a dam has been placed across the mouth of Crab Creek. At present there is no visible overflow from Moses Lake, but there is probably a considerable loss by seepage through the sand. This seepage water reappears as perennial springs near the south side of the dunes and forms lower Crab Creek.

East of the old glacial-stream channel the Dunesand is lighter in color and finer in texture. It is composed of sand blown from the west side of the old channel and is underlain by the Ephrata fine sandy loam.

The "potholes," which were formerly the retreat of large bands of wild horses, now afford pasturage, water, and protection for horses and cattle. The Dunesand is not adapted to dry farming. At present irrigation is impracticable.

EPHRATA SANDY LOAM.

The soil of the Ephrata sandy loam to a depth of 16 to 20 inches is a rather dark gray to grayish-brown sandy loam, carrying a relatively large quantity of fine and coarse sand and fine gravel, with but little sand of medium grade. A thin mantle of sand and fine gravel occurs in patches, especially on the portions bordering the Winchester coarse sand. On the steep slopes toward other adjacent types and on the ridges and mounds occurring in the type the soil, particularly

the first 3 or 4 inches, is compact and firm, yet breaks up readily when cultivated. This compact structure varies over different portions of the type according to the percentage of silt in the soil. Though the wind drifts a freshly broken surface to a limited extent, the soil quickly settles together and becomes firm enough to resist wind action.

The subsoil consists of fine gravel from one-fourth to one-third of an inch in diameter, with interstitial sand of different grades. Well borings indicate that over large areas of the type this formation extends to a depth of 100 feet or more. The change from soil to subsoil is rather abrupt, although there is a slightly greater quantity of sand and gravel in the lower part of the soil and a noticeably greater proportion of sand, especially fine sand, in the upper part of the subsoil. The sand and gravel of both soil and subsoil consist of rounded and subangular fragments of basalt, which are black when moist, but assume a grayish hue when dry.

The largest body of this type occupies the north-central part of the survey and is locally known as the Morrison Flat. Well-defined bluff lines separate this area from all the surrounding types except the Winchester coarse sand. In the latter case the drifting sand has rendered the boundary somewhat obscure. Small areas of the type occur in T. 19 N., R. 24 E., T. 20 N., R. 28 E., T. 16 N., R. 27 E., and in T. 17 and 18 N., R. 28 E., and in T. 20 N., R. 26 E.

The Morrison Flat has the appearance of an almost level plain, dotted here and there with low, broad ridges and mounds. Near the northern and western margin of the type the topography is slightly rolling, while on the south and east a number of small draws break the otherwise even bluff lines. The small isolated areas of the type are comparatively level. The loose porous subsoil gives good underground drainage.

The character and structure of the type seem to indicate that the coarse material and subsoil represent a portion of the outwash plain formed by the large glacial stream which traversed the eastern part of the survey, and that the soil is probably a mixture of the fine material brought down by the stream and that distributed over the area by wind action. Originally the Ephrata sandy loam was covered with a heavy growth of black sage and desert grasses. A number of flowering plants, especially the sunflower, are common in their season.

Scattered over the type are a few small spots, almost devoid of vegetation. An alkali determination of a sample taken from one of these spots showed less than 50 parts per 100,000 of dry soil of alkali salts. They owe their formation rather to an accumulation of silty material from the slightly higher surrounding soil and their unproductiveness to the hard crustlike structure rather than to the

presence of alkali. An application of stable manure would doubtless render these spots more productive.

Nearly all of the type open to settlement has been cleared and put under cultivation. Fair yields of wheat and rye are secured in favorable seasons, but the average yield is quite low. The greater part of the rye and of the wheat, if conditions are not favorable for its filling properly, are cut for hay. Summer fallowing is practiced, but it does not conserve sufficient moisture to produce profitable yields year after year. The type has such a low moisture holding capacity that the most successful methods of dry farming will not produce sufficient yields to justify the extra labor. The undeveloped sections afford good pasturage.

Its topography, good natural drainage, freedom from drifting sand, and ease of irrigation combine to make the type desirable and valuable for intensive farming. This can not be practiced until the type is put under irrigation. When irrigated it is adapted to alfalfa, vegetables, and fruits. Only one small tract of this type is being irrigated at present, but there seems to be a good underground supply of water for irrigation at depths ranging from 125 to 175 feet.

Comparatively little of the type has been sold recently, as it is being held at too high a price for profitable returns under the present system of farming. The current value of the land depends upon the nearness to market and improvements. Sales at \$25 to \$50 an acre are reported, the land being bought chiefly for speculative purposes.

The following table gives the average results of mechanical analyses of samples of the soil and subsoil of the Ephrata sandy loam:

Mechanical analyses of Ephrata sandy loam.

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
550818, 550832.....	Soil.....	13.6	15.9	6.1	17.1	16.8	26.1	4.5
550819, 550833.....	Subsoil.....	52.2	24.9	4.6	5.6	3.3	7.1	2.5

EPHRATA STONY FINE SANDY LOAM.

The surface of the greater part of the Ephrata stony fine sandy loam is characterized by low broad mounds of light grayish-brown gravelly fine sandy loam of silty texture, underlain with a bed of cobbles and bowlders. In the intervening areas the subsoil is encountered at very shallow depths or outcrops at the surface. The mounds vary from 1 foot to 2½ feet in height and from 10 to 25 feet in diameter and are practically free from bowlders. Where the mounds do not occur and the soil is spread evenly over the subsoil the depth of the soil varies from 6 to 14 inches and many bowlders

of various sizes are scattered over the surface. There are many small areas where the surface boulders are very numerous. The type differs from the Ephrata fine sandy loam in having a shallower soil, a higher gravel content, more boulders upon the surface, and in the presence of mounds. These two types grade into each other and the boundary between them is arbitrary. Small undifferentiated areas of the Ephrata fine sandy loam occur within the limits of this type.

The Ephrata stony fine sandy loam occupies an almost continuous area in T. 20 N., R. 25, 26, 27, and 28 E., in the northern part of the survey. Several small areas occur in the southeastern part of the survey.

The type has a somewhat terraced topography, though not as marked as that of the Ephrata fine sandy loam. The surface of the benches is gently rolling to rolling with steep bluffs between the benches. The type is crossed by Crab Creek and by small coulées¹ and draws. The drainage is excessive on account of the open nature of the subsoil. No alkali is found in this type.

The Ephrata stony fine sandy loam consists of a mixture of rounded basaltic gravel, cobbles, boulders, and finer material, which were probably deposited as an outwash plain by an old glacial stream. Both water and wind action have combined to distribute the finer material and to form the soil of the type.

The type is covered with a scant growth of black sage and other desert shrubs. There is a scattering growth of bunch grass. The surface of this type is firm and the soil drifts only slightly when broken. The type is droughty and not adapted to dry-farming methods. Within the last few months a small acreage has been cleared and either set to trees or sowed to alfalfa. Water for irrigation is secured at depths of 125 to 175 feet. The cost of clearing and leveling the type for irrigation is probably higher than in case of any other arable soil in the survey. For one tract on this type the cost of preparing the land for seeding cost between \$40 and \$50 per acre. Under irrigation the type should be adapted to fruit, berries, certain truck crops, and alfalfa.

Land of this type is being held at a high price, and practically none of it has changed hands recently. There has been very little demand for it on account of its shallow soil and rocky nature.

The following table gives the average results of mechanical analyses of samples of the soil of the Ephrata stony fine sandy loam:

Mechanical analyses of Ephrata stony fine sandy loam.

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
550840, 550841.....	Soil.....	6.1	5.2	4.3	14.8	21.3	41.2	6.7

¹ The word "coulée" is here used in its local meaning.

EPHRATA FINE SANDY LOAM.

The soil of the Ephrata fine sandy loam, to a depth of 12 to 24 inches and occasionally to 3 feet, consists of a light grayish brown to light yellowish brown fine sandy loam, carrying a relatively high percentage of very fine sand. Over portions of the type rounded gravel occurs in the surface and throughout the soil. A few boulders are also scattered over the surface of the type. The subsoil is a mass of cobbles and boulders with some interstitial gravel to a depth of 3 or 4 feet and varying quantities of fine earth. This formation extends to a depth of 100 feet or more. The greater part of the coarse material consists of rounded fragments of basalt with a few fragments of granite. Small areas occur throughout the type where the soil is very shallow and the boulders of the subsoil outcrop on the surface. Along the steep bluffs between the benches occupied by the type the subsoil outcrops as a mass of loose gravel, cobbles, and boulders.

In those portions of the area covered by the type occurring in the southeastern part of T. 18 N., R. 28 E., or lying east of Willow Creek Coulée and Pelican Horn, boulders are generally absent from both soil and subsoil, the subsoil consisting principally of waterworn basaltic gravel. In the more northern of these districts a considerable quantity of gravel occurs in the soil material and these parts of the type are indicated upon the map by gravel symbol as a gravelly phase.

Many of the gravel of the subsoil have a white coating of lime which sometimes cements the subsoil into a hardpan.

The type occupies large areas in the eastern and northeastern parts of the survey, or on each side of Moses Lake. A smaller body occurs southeast of Winchester in T. 20 N., R. 25 E. There are two areas in the southeastern part of the survey, one in T. 16 N., R. 26 and 27 E., the other in T. 16 N., R. 28 E. A body of this type occurs along the north side of survey in T. 20 N., R. 25 and 26 E.

The coarser material of the type, gravel, cobbles, and boulders, was probably deposited by the flood waters of an old glacial stream, while the presence of the fine material is probably due to the agencies of both water and wind.

The Ephrata fine sandy loam occupies level to gently rolling benches separated from each other by steep bluffs from 10 to 100 feet or more in height. In general, the main body of the type has a terraced topography. Hiawatha or Pleasant Valley crosses the type in T. 19 N., R. 27 E. and the western wall of this valley, a bluff over 100 feet in height, separates the Ephrata fine sandy loam from the Ephrata sandy loam on the west. Willow Creek Coulée traverses the type in T. 19 and 20 N., R. 28 E.

The chief topographic feature of the Ephrata fine sandy loam is the old glacial-stream channel which has a rather winding course across the type and is now occupied by Moses Lake. As the land rises quite abruptly from the shore of the lake the water of the lake has had little or no influence in forming the topography of the surrounding type. On the inside of the bends of the old channel, now occupied by the lake, the land rises to the higher uplands by a series of benches or terraces, the lowest of which have an elevation of 25 to 50 feet above the level of the lake. On the opposite side of these bends the land rises abruptly to the higher uplands 100 to 150 feet above the level of the lake.

On account of the open structure of the subsoil the drainage is excessive and crops suffer from drought. The type is free from alkali.

The Ephrata fine sandy loam supports a good growth of black sage and scattering bunch grass. Other small desert plants thrive in their season.

Only a small proportion of the type is cleared and under cultivation. On account of the surface bowlders which must be removed, the cost of clearing this type is slightly higher than that of any other type in the survey except the Ephrata stony fine sandy loam. In its natural state the surface of the soil is compact and firm and does not drift. It breaks up readily and forms a mellow seed bed, which is slightly drifted by the wind. Rye and wheat are grown to a limited extent, but the yields are light and the crops are usually cut for hay. On areas with the more gravelly subsoil more certain and higher yields are secured. A large percentage of such land open to settlement is cleared and sowed to wheat and rye. Fair yields of potatoes are secured on small irrigated patches.

During the last two years quite an acreage has been cleared and set to orchards. The young trees are making a good growth. Jonathan, Stayman Winesap, Rome Beauty, Spitzenberg, and Winesap are the principal varieties. A supply of water for irrigating purposes is secured at depths ranging from 50 to 150 feet. A shaft about 5 feet in diameter is sunk into the bed of bowlders until it reaches a few feet below the level of the flow of underground water. At present the greater development is taking place in the shallow water belts following the Hiawatha Valley and the lower benches along Moses Lake.

Only one orchard on the type is old enough to be in bearing. This orchard is producing fruit of good quality, which finds a ready local market. (Pl. II, fig. 2.) Apples, peaches, apricots, pears, and cherries seem to do equally well. A small acreage of grapes of the Concord and Worden varieties have been set out. The vines are making a vigorous growth, but are too young to enable a prediction whether grapes will prove a success on a commercial scale. (Pl. III, fig. 1.)

Alfalfa does well on irrigated land. Three to four cuttings are secured, with a yield of 5 to 7 tons per acre. The check system of irrigation is used. Under irrigation potatoes yield from 300 to 500 bushels per acre. This type is also adapted to certain varieties of truck crops and to berries.

Undeveloped land of this type is being held at \$50 to \$150 an acre. Sales at \$75 to \$100 an acre are reported. The present value is determined chiefly by the depth to water. The greater part of the type is distant from markets.

The following table gives the average results of mechanical analyses of samples of the soil of the Ephrata fine sandy loam:

Mechanical analyses of Ephrata fine sandy loam.

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
550844, 550845.....	Soil.....	3.3	1.9	1.4	23.7	30.8	33.6	5.1

BEVERLY SANDY GRAVEL.

The soil of the Beverly sandy gravel, to a depth of 12 to 15 inches, consists mainly of waterworn gravel and small rounded cobbles, with a little finer material, consisting of fine sandy loam or fine sand, filling the interstitial spaces and often forming a shallow covering over the coarser gravelly deposits. Large rounded bowlders or fragments of basalt are sometimes found on the surface and in the soil, but these do not occur in sufficient quantity to give the soil the characteristics of a stony loam. The subsoil is composed of a compact mass of gravel, cobbles, and small bowlders and contains little or no fine interstitial material.

The largest area of the Beverly sandy gravel occurs in the narrow valley on the west side of the Columbia River, a few miles above Beverly. It occupies the narrow strip of valley land lying between the river and the steep slopes of the adjacent uplands. Two other areas of very small extent occur on the east side of the river, one near Trinidad and one a few miles north of Beverly. The areas occupied by this type have only a slight elevation above the level of the river and could be put under irrigation without difficulty. The topography varies from level to gently undulating and the coarse porous texture of the soil and subsoil insures good underdrainage.

The soil is derived mainly from the coarser deposits laid down by flood waters of the Columbia River, and from finer deposits of sand, which were primarily deposited by the water of the stream and have later been modified to some extent by the action of winds.

This type is not adapted to dry farming or to crops which require the constant cultivation of the soil, but existing orchards under irrigation demonstrate that with a sufficient water supply it can be very profitably utilized for the growing of fruits. Only a very small acreage has been developed agriculturally.

A mechanical analysis of a sample of soil gave the following results:

Mechanical analyses of Beverly sandy gravel.

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
550851.....	Soil.....	2.7	2.8	2.7	20.3	34.4	29.4	7.6

BEVERLY FINE SAND.

The soil of the Beverly fine sand consists of a grayish brown or very light brown fine sand, 12 to 15 inches deep, containing variable quantities of coarse, medium, and fine sand. The greater proportion of the soil has a medium to fine texture, but the material from which it is derived has been modified by the action of winds, and the texture often varies over areas of small extent. The subsoil is similar in texture to the soil, but is slightly lighter in color. At a depth of from 2½ to 5 feet the subsoil is underlain by a mass of gravel, cobbles, and small boulders.

The Beverly fine sand occurs in the western part of the area, and occupies a part of the narrow strip of land which lies between the channel of the Columbia River and the base of the bordering bluff. Small mounds of gravel and rounded boulders, which are covered only to a very shallow depth by the drifting sands, occur at intervals in this type. Near the foot of the bluffs this soil often contains a considerable amount of coarse sand and small gravel, and cobbles are found scattered over the surface or mixed with the soil and subsoil. The gravel is more plentiful on areas where the underlying coarse deposits are found near the surface, while on adjoining areas, where the drifting sand covers these coarser deposits to a depth of many feet, the soil is free from gravel or boulders.

The Beverly fine sand has an elevation of 5 to about 30 feet above the level of the river, and almost all of this land is irrigable. Large areas occur which are comparatively level, but the low mounds and ridges formed by the drifting of the sand give the type as a whole a rather uneven surface. The soil is well drained, and the coarse gravelly deposit forming the deep subsoil insures good under-drainage for the irrigated land.

The material forming this soil is mainly alluvial in origin, but it has been modified to a considerable extent and includes some wind-

blown material. The coarse deposits of rounded rock and gravel were laid down along the flood plain of the Columbia at an earlier period, and the fine sandy material was first deposited by water along the course of the streams and later drifted over the narrow valley lands. One comparatively large area of this type has been put under irrigation. This tract is cultivated principally to fruits. The young orchards are in a flourishing condition. Grain, small fruits, vegetables, and alfalfa are also grown to a limited extent and produce very profitable yields.

Water for irrigation is obtained from the Columbia River.

None of the unirrigated land is under cultivation, with the exception of a few small tracts, less than an acre in extent, used for gardening. The location and topography of this type permits irrigation without difficulty, and with sufficient water it will produce very profitable yields.

The following table gives the results of mechanical analyses of samples of the soil and subsoil of the Beverly fine sand:

Mechanical analyses of Beverly fine sand.

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
550801.....	Soil.....	1.0	8.1	8.0	53.6	24.0	3.5	1.2
550802.....	Subsoil.....	.6	3.7	12.3	60.2	17.2	4.7	1.3

BEVERLY GRAVELLY FINE SANDY LOAM.

The soil of the Beverly gravelly fine sandy loam consists of 12 to 20 inches of a brownish gray to light yellowish brown or buff fine sandy loam containing a large proportion of small water-worn gravel. The gravel does not occur on surface in great quantities but is found mixed with the finer material throughout the entire section of surface soil. The subsoil consists of a compact mass of rounded gravel and small cobbles, the interstitial material being composed of various grades of sand and fine gravel. Both the soil and subsoil are comparatively free from large bowlders or angular rock fragments.

This soil occurs in the narrow valley of the Columbia River in the southwestern part of the survey and comprises a total area of about 2 square miles. The topography is level to gently undulating, but the area as a whole has a gentle slope from the foot of the steep bluffs bordering the valley down to the level of the stream. The porous character of the deeper subsoil and the elevation of the land above the level of the river give excellent natural drainage.

The Beverly gravelly fine sandy loam is derived principally from material deposited by the flood waters of the Columbia. The deposits of rounded gravel and small cobbles which form the subsoil were laid down at a time when this narrow strip of valley land formed part of the channel of the river. The boundary between the soil and subsoil is very distinct and the uniform depth of the surface deposit and the presence of the fine gravel mixed with the sand indicates that this material has also been deposited by the waters of the stream. The surface material, however, has been modified to some extent by the action of winds.

None of this type is cultivated at present, but the greater proportion of it is now being put under irrigation. When irrigated it should be well adapted to fruit and to a wide range of general farm crops.

The following table gives the results of a mechanical analysis of a sample of the soil of the Beverly gravelly fine sandy loam:

Mechanical analysis of Beverly gravelly fine sandy loam.

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
550852.....	Soil.....	6.2	2.9	1.5	9.1	38.1	35.8	6.4

RED ROCK FINE SANDY LOAM.

The soil of the Red Rock fine sandy loam, to an average depth of 12 to 24 inches, consists of a light-gray to grayish-brown or drab compact fine sandy loam. The subsoil consists of a compact fine sandy loam slightly lighter in color than the surface soil. A hard compact clay or clay loam is sometimes encountered in the deeper subsoil, while in other localities beds of waterworn gravel occur at depths of 3 to 6 feet below the surface. A few small areas occur in the type, when both the soil and subsoil contain a considerable quantity of gravel. In these areas the fine earth of the soil is a drab or brown fine sandy loam or loamy fine sand. This phase of the type occurs at the base of some of the steep bluffs which border Crab Creek Valley (see Pl. III, fig. 2), and much of the coarser material in the soil has been brought down from the adjacent uplands. These gravelly areas, however, are of very small extent. Several small areas of the Red Rock fine sandy loam occur in the southern part of the area, forming narrow strips of land between the present channel of Crab Creek and the bluffs which rise abruptly to the adjacent uplands. The surface material has been drifted into low mounds and ridges, and the topography as a whole is uneven.

With the exception of the few small areas underlain by the compact impervious clay the type is usually well drained.

The Red Rock fine sandy loam is derived partly from material laid down by water along the broad glacial valley now occupied by Crab Creek, but much of the surface material is locally wind blown in origin. Only a very small acreage of this type has been cultivated. Alkali occurs in sufficient quantities to be harmful to crops in almost every area. The greater concentrations are found in shallow depressions occurring between the low sandy mounds or ridges. The native vegetation consists mainly of greasewood, sagebrush, and salt grass.

The following table gives the average results of mechanical analyses of samples of the soil and a single analysis of the subsoil of the Red Rock fine sandy loam:

Mechanical analyses of Red Rock fine sandy loam.

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
550830, 550856.....	Soil.....	0.5	1.0	2.2	25.9	36.3	26.4	7.7
550831.....	Subsoil.....	.1	1.0	2.9	29.9	44.4	16.9	4.6

The following samples contained more than one-half of 1 per cent calcium carbonate (CaCO_3): No. 550830, 1.18 per cent; No. 550831, 2.45 per cent.

RED ROCK CLAY.

The soil of the Red Rock clay, to an average depth of 12 inches, is a gray, drab, or slate colored, sometimes slightly mottled, clay, usually of rather light texture. The texture of the soil varies slightly according to local differences in topography or drainage conditions, being heavier in the depressions and more loamy in areas having better drainage. The subsoil is a light-brown to gray fine sandy loam sometimes containing thin layers of silty material. In some places the subsoil is underlain at a depth of 12 to 36 inches by a brown hardpan. Where this occurs within 12 to 15 inches of the surface, the fine sandy loam subsoil is lacking.

The type occurs in the southern and southeastern parts of the area, forming a narrow strip on each side of Crab Creek. In the southeastern part of the area small bodies of this soil are covered with a shallow deposit of sand washed down from adjacent areas of drifting sand, at times when Crab Creek served as an outlet for the flood waters of Moses Lake. The position of this soil in the Crab Creek Valley subjects it to the accumulation of drainage water from the uplands and the greater proportion of the type is in a very poorly drained condition.

The soil is derived principally from the finer material washed down from the adjoining uplands and deposited in this valley under

very poorly drained or swampy conditions. A considerable quantity of alkali is present in both the soil and subsoil. In some of the low depressions the alkali content, to a depth of 6 feet, exceeds 3,000 parts of alkali salts per 100,000 of dry soil.

None of the Red Rock clay is cultivated, but it is used to a limited extent as pasture land. The native vegetation consists mainly of greasewood, salt grass, and other alkali plants.

The following table gives the average results of mechanical analyses of samples of the soil and subsoil of the Red Rock clay:

Mechanical analyses of Red Rock clay.

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
550828, 550846.....	Soil.....	0.0	0.2	2.0	19.1	11.9	33.0	33.7
550829, 550847.....	Subsoil.....	.2	2.0	4.7	36.1	17.7	29.3	9.9

The following samples contained more than one-half of 1 per cent calcium carbonate (CaCO_3): No. 550828, 20.90 per cent; No. 550829, 21.40 per cent; No. 550846, 17.36 per cent; No. 550847, 9.38 per cent.

NAYLOR SILT LOAM.

The Naylor silt loam is composed of alluvial, colluvial, and wind-blown material from the surrounding types and occupies small playa-like bottoms in Willow Creek, Crab Creek, and Ryegrass Coulees. The soil is gray in color and varies in texture from a silt to a fine sand, though typically of silt loam texture. It is underlain by bed-rock or boulders at depths varying from 2 to 10 feet.

The type is nearly level and covered with a growth of salt grass and greasewood. The drainage is very slow. Alkali has accumulated in quantities varying from less than 200 parts to over 3,000 parts of alkali salt per 100,000 of dry soil. Alkali crusts are common, particularly in Willow Creek Coulee, where the highest percentage of alkali is found in the soil.

The greater proportion of the type is not suited for farming until some of the alkali has been removed. Practically none of the type is under cultivation.

The following table gives the average results of mechanical analyses of samples of the soil of the Naylor silt loam:

Mechanical analyses of Naylor silt loam.

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
550848, 550849.....	Soil.....	0.2	0.5	0.9	9.4	24.2	54.5	10.1

The following samples contained more than one-half of 1 per cent calcium carbonate (CaCO_3): No. 550848, 8.13 per cent; No. 550849, 8.35 per cent.

MEADOW.

The soil of the Meadow type is subject to considerable variation in color and texture. It occurs in low depressions recently covered by waters of Moses Lake. Along Parker and Pelican Horns the soil is a dark-brown sandy loam to silt loam, underlain at shallow depths by bowlders or bedrock, and supports a growth of salt grass and scattered greasewood. Along Crab Creek north of Moses Lake the type is chiefly Muck and Peat. Here it is swampy and supports a growth of tules, cattails, and water-loving grasses.

The area in T. 17 N., R. 28 E. is sandy with many shallow depressions in which water stands throughout the year. A few small dunes occur within this area. Greasewood and salt grass are characteristic plants.

The Meadow occupies low flat areas which were covered with water when Moses Lake was at its highest stage. An attempt is being made to raise the water of the lake to its former level, which, if successful, will flood the areas of Meadow near the lake.

The type is used for grazing. A large proportion of it contains considerable alkali.

COHASSET SILTY SANDY LOAM.

The soil of the Cohasset silty sandy loam consists of 10 inches of a light reddish brown sandy silty loam, containing considerable coarse sand and fine gravel and variable quantities of gravel, small rock fragments, and bowlders. In areas lying adjacent to types of fine sand or fine sandy loam the surface is comparatively free from gravel and rock fragments, but the greater proportion of the type is more or less stony, and small areas approach a stony loam in texture. The subsoil is a heavy light-brown loam containing a higher percentage of silt and less fine sand than the surface soil. The subsoil, however, is frequently very shallow, and a mass of rounded bowlders and fragments of basaltic rock is encountered at a depth of 20 to 30 inches below the surface.

The area of this soil which occurs in the southwestern part of the survey on the west side of the Columbia River, contains a larger proportion of small gravel and fragments of basalt than the area on the east side of the river. In this locality the underlying rock is encountered at a very shallow depth, and small areas of rock outcrop are of frequent occurrence. Another small area of the type is found in the western part of the survey just north of Frenchman Hills.

This soil type is formed of material derived from the weathering of basaltic rocks and deposits of wind-blown origin. The topography varies from comparatively level to very gently rolling, but the more

level areas are often intersected by deep erosions or narrow, rocky ravines.

None of this land is irrigated and only a small acreage is under cultivation. A few areas of the less stony phase are used for the growing of wheat and rye and during favorable seasons produce fair yields. With irrigation a large percentage of the type could be profitably utilized for fruit growing.

The following table gives the results of a mechanical analysis of a sample of soil of this type:

Mechanical analysis of Cohasset silty sandy loam.

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
550809.....	Soil.....	10.7	10.6	3.2	13.4	14.6	42.1	5.4

ROUGH BROKEN LAND.

The area mapped as Rough broken land comprises the lands which have such a rough and mountainous topography or are of such a stony character that they can not be used for farming. Large areas of rock outcrop occur at frequent intervals and the steeper slopes are often formed by almost perpendicular walls of basalt. The soils are shallow and the surface is usually strewn with large boulders and angular fragments of basalt.

Large areas of this kind occur along Saddle Mountain in the extreme southern part of the area and in the mountainous district in the southwestern corner of the survey. Other smaller areas lie along the steep bluffs bordering the valley of the Columbia River. The greater proportion of this land is too steep and rocky to be of value even for grazing.

ALKALI.

Most of the soils of the area are at present entirely free from harmful accumulations of alkali. Alkali determinations of each foot of soil to a depth of 6 feet were made at intervals on the various types of upland soil and the tests rarely showed the presence of more than a trace of injurious salts. Small areas containing from 200 parts per 100,000 to more than 3,000 parts per 100,000 of the soil occur along Crab Creek Valley, both above and below Moses Lake; in the deep depressions surrounded by areas of Rough broken land; in the small potholes which occur among the higher sand dunes; and in the bottom of Willow Creek and several other large coulées. The majority of these areas are small, but a large proportion of the alluvial soil in the lower Crab Creek Valley contains alkali in harmful amounts.

Alkali accumulation in the Quincy area is due in every case to poor drainage conditions. The "potholes" are completely surrounded by high dunes of drifting sand. They receive the drainage and seepage water from the surrounding lands and have no natural drainage outlet. Water often collects and stands in these depressions for long periods. The same drainage conditions are found in other localities where deep depressions occur which are almost surrounded by walls of basaltic rock.

The land occupying the lower Crab Creek Valley is also poorly drained. Although this valley receives the surface drainage of a large area of gently rolling uplands the stream has such a slight fall that during the greater part of the year there is no running water, but only a series of marshy ponds along its channel.

A more adequate drainage system would be necessary in many parts of the Quincy Valley if any extensive areas were put under irrigation. The upper 6 feet of the irrigable soils is at present almost free from alkali, but if the seepage water of a large irrigated area is allowed to collect and evaporate in the shallow depressions which occur at intervals in various parts of the area there is danger that the soils of these poorly drained areas would eventually contain alkali in harmful quantities.

The following table gives the analysis of alkali crusts obtained from the lower Crab Creek Valley:

Analysis of alkali crusts formed in Red Rock clay.

Constituent.	Parts per 100,000.
Ions:	
Sodium (Na).....	654
Calcium (Ca).....	Trace.
Potassium (K).....	Trace.
Magnesium (Mg).....	Nil.
Chlorine (Cl).....	492
Sulphuric acid (SO ₄).....	750
Conventional combinations:	
Sodium chloride (NaCl).....	812
Sodium sulphate (Na ₂ SO ₄).....	1,031

IRRIGATION.

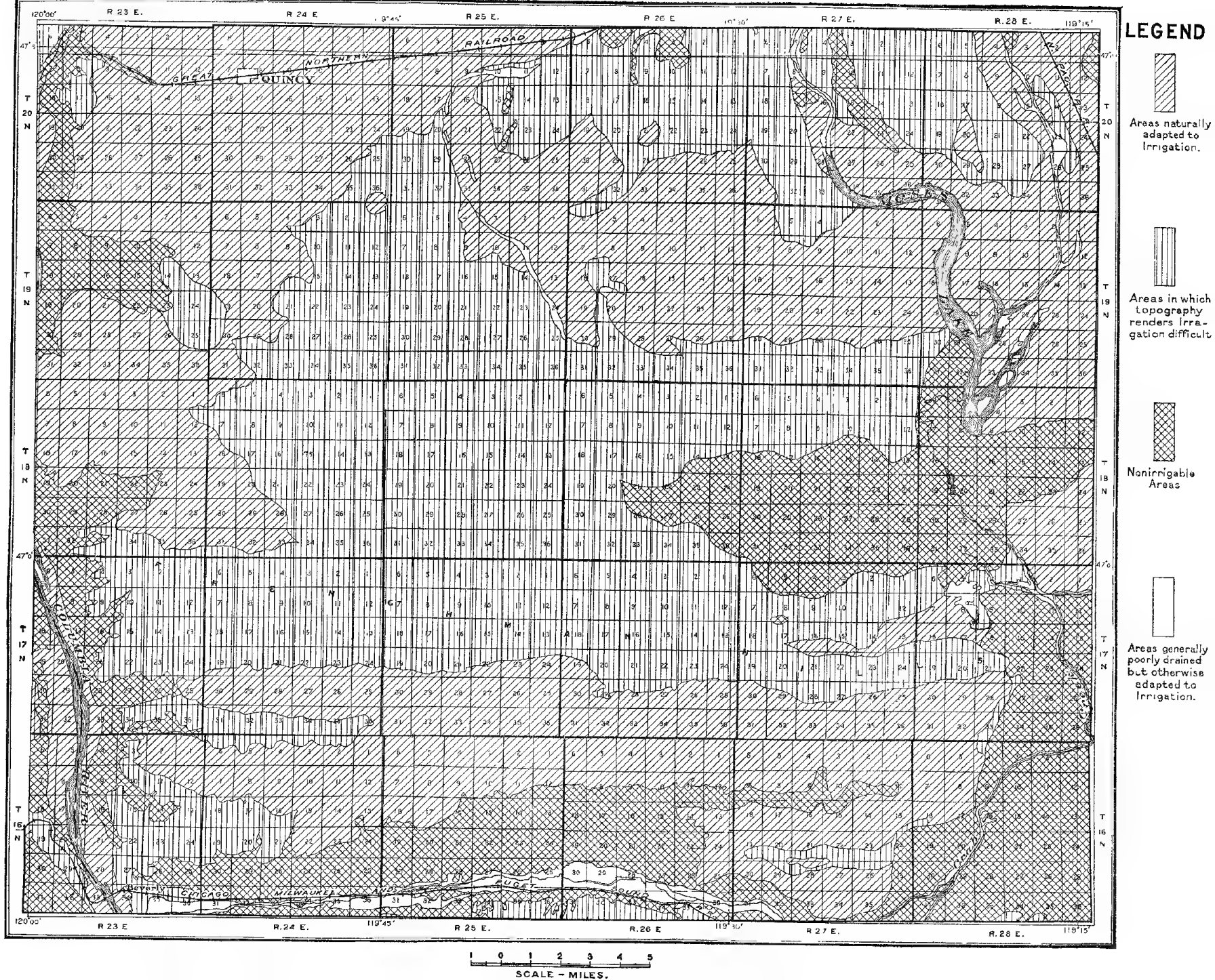
A very large part of the area surveyed may be put under irrigation. The general topography and character of the soils in some sections, however, make irrigation less difficult and much less expensive than others. For the purpose of presenting these features in their relation to the development of irrigation, the lands of the area have been classified broadly into four general classes: (1) Areas

where both the soil and topography are well adapted to irrigation; (2) areas where the soils are suitable for agriculture but the topography makes irrigation difficult; (3) areas where irrigation is impracticable; (4) areas generally poorly drained but otherwise adapted to irrigation. The distribution of lands of these several classes are shown in figure 7.

The first class comprises a large proportion of the land occupying the Quincy Valley, covered by the soils of the Quincy series. The soils are principally sandy loams, fine sandy loams, and fine sands, and the topography varies from almost level to very gently undulating. The area covered by this class also includes the bodies of the Ephrata sandy loam and of the Ephrata fine sandy loam, occurring in the eastern, north-central, and northeastern parts of the survey. A large proportion of the land lying south of the Frenchman Hills and west and north of the lower Crab Creek Valley can also be included in the first class, although the topography is slightly more rolling than that of the Quincy Valley.

The second class includes the more rolling and hilly land, such as that occupying the low range known as Frenchman Hills. The soils of this belt are similar in texture and structure to those more level types found on each side, but the hills rise to an elevation of from 300 to about 500 feet above the level of the adjacent plains and the surface is so rolling that irrigation would be difficult and costly. It could be effectively followed only through installation of a piping or closed-conduit system, and then only by terracing the slopes. This class also includes extensive areas covered by the soils of the Winchester series and by the Quincy fine sand lying north of the Frenchman Hills, and by the Ephrata stony fine sandy loam occurring in the northeastern part of the survey. While occupying undulating plains, the areas of more sandy soils included under this class, such as the Winchester coarse sand, Winchester sand, and Quincy fine sand, are not as well adapted to irrigation as most of the land included in the first class. The soils have been drifted into low mounds and ridges, causing the surface of some areas to be quite rolling and requiring leveling for irrigation, and the loose incoherent structure of the soils and subsoils would cause a considerable loss of water by seepage. The Ephrata fine sandy loam has a comparatively level topography, but owing to the necessity of clearing the soil of the large boulders scattered over the surface it is more difficult to get it in condition for cultivation and irrigation than the soils of a less stony character.

The third class includes the Dunesand and a limited area of the Winchester coarse sand lying adjacent to the dunes, which has been drifted to such an extent that it has many of the characteristics of the Dunesand. It also includes the areas of the rock outcrop phase



of the Quincy fine sandy loam and of the Rough broken land. The difficulty of leveling the Dunesand and higher mounds and ridges in the Winchester coarse sand makes the irrigation of these areas impracticable. Small areas of sandy or fine sandy loam, comparatively free from stones, which could be utilized for agriculture, occur at intervals throughout the areas of the rock outcrop phase of the Quincy fine sandy loam, but they are of such limited extent and are surrounded by such large bodies of rough and stony land that it would be impracticable to attempt to irrigate them. The Rough broken land has such a steep topography and the soils are so stony that it is not adapted to agriculture.

Class four includes inextensive areas of stream bottoms, terrace or meadow lands. Some of the steam terraces included in this class are fairly well drained and could be utilized for irrigation provided water could be brought to the land without great expense. In some cases this can be done, but most of the local valley and meadow areas covered by this class are poorly drained and frequently carry injurious quantities of alkali salts at the present time. These conditions would under irrigation become acute, and in any enterprise concerned with the irrigation of the lands provision for underdrainage should be made.

The cost of irrigation by pumping from wells varies considerably in different localities, depending upon the depth at which a sufficient supply of water can be obtained and upon the lift required to put the water on the land. In the region around Moses Lake the depth of the wells varies from about 125 to 200 feet. It is said by those who have made observations in wells on each side of the old glacial river channel that there is a strong flow of underground water toward the main basin now occupied by the lake. Over a large part of the Quincy Valley a sufficient flow of water is obtained at a depth of from 200 to 300 feet. In the southeastern part of the valley north of Frenchman Hills an adequate supply is obtained in some localities at a depth of 30 to 50 feet. Along the coulées that branch off from Crab Creek Valley water is also obtained at relatively shallow depths. In the uplands lying south of Frenchman Hills and north of the Crab Creek Valley it is necessary to go much deeper to get a sufficient supply of water than it is in the Quincy Valley. Water was obtained in the western part of this section at a depth of about 700 feet, while to the east the wells vary in depth from 275 to about 400 feet. None of the wells in this locality, however, are used for irrigation purposes. The cost of wells varies to some extent in different localities, but for the average well it is estimated to be about \$5 per foot.

Only a small acreage of the alluvial land, lying between the stream and the adjacent bluffs is at present irrigated by water obtained from the Columbia River. All of the land occupying this

lower bench could be watered at a comparatively small cost, but the adjacent uplands have such a great elevation above the level of the streams that the water is not considered available for irrigation purposes.

The power for the pumping plant is in almost every case furnished by gasoline engines, but a few small areas of very limited extent are irrigated with water pumped by windmills. Reservoirs are very seldom used, the water being pumped directly from the wells to flumes, which distribute it over the land. The furrow system of irrigation is in general use except in the alfalfa fields. For alfalfa the check or flooding system is preferred. The principal crops grown under irrigation at the present time are orchard fruits, grapes, small fruits, potatoes, melons, alfalfa, and a small quantity of vegetables for home use. Oats have also been grown on a small acreage.

The area of irrigated land is as yet so small that no data can be obtained as to adequacy of the supply of water obtained from wells. Up to the present time, however, the level of the water in the wells remains practically unchanged when water for irrigation is being pumped out at the rate of 150 to more than 500 gallons per minute.

A plan is now being considered to irrigate an area of several hundred square miles in the Quincy Valley by bringing water in a canal from some point on the Wenochee River.

Analyses of irrigation waters show small quantities of alkali salts. A sample from the lower course of Crab Creek contained 70 parts per 100,000, mainly bicarbonates with some chlorides and carbonates and less of the other soluble salts. This sample was the most concentrated of any examined. A sample of water from Moses Lake taken during the progress of the survey showed 6 parts chlorides and 50 parts bicarbonates and a total soluble salt content of 60 parts per 100,000. A later sample of this water collected in the early spring of 1912 was found to contain but 39 parts per 100,000 of soluble mineral salts, of which 26 parts consisted of bicarbonates, mainly of sodium. A sample of water from a well near Quincy contained 40 parts per 100,000, mainly bicarbonates and chlorides.

The total salt content of these waters would not be considered excessive for irrigation purposes, as waters are successfully used in irrigated areas having several times this salt concentration. A large proportion of the total salt content, however, consists of bicarbonates, and under conditions of deficient drainage the accumulation of the highly corrosive and injurious black alkali or sodium carbonate might locally result. With the prevailing favorable slope and sub-drainage conditions it would seem that but little or no injury need be feared from the irrigation of the soils of the Ephrata series or other of the higher-lying soils by waters taken from the lake or from an underground source. Some danger of the accumulation of alkali salts in injurious amounts in local poorly drained areas of lower-

lying soils of the Naylor and Red Rock series, where an appreciable concentration of salts already occurs, may be anticipated.

CHEMICAL ANALYSES OF THE SOILS.¹

In addition to the physical analyses of typical samples of the soils of the area, chemical analyses were also made. For this purpose samples were taken by means of a soil auger to the depths indicated in the following table and were sent to the laboratory at the University of Washington.

It has come to be generally recognized that the mineral elements in the soil of the most interest to the agriculturist are calcium, potassium, phosphorus, and nitrogen. For technical reasons, which need not be explained here, these are generally spoken of as lime (calcium oxide), potash (potassium oxide), phosphoric acid (phosphorus pentoxide), and nitrogen. Nitrogen is also sometimes spoken of as ammonia, although undoubtedly present in the soil in other forms. These constituents are the ones which it is sought to add to the soil in commercial fertilizers. Other mineral elements are undoubtedly needed by growing plants, but they are always abundantly present in the soil and have no great importance in fertilizer practice.

Besides analyzing the soil for the above constituents, it is now recognized that the chemist can add important information by determining the lime requirements of a soil; that is, the amount of lime which must be added to render the soil certainly neutral or slightly alkaline. The action of the lime is probably quite complex in most cases, neutralizing any acids which may be present, inducing a much better flocculation or crumbling of the soil, improving its tilth, aeration, etc., which functions are most important for the growth of desirable kinds of bacteria in the soil, and especially those kinds which gather nitrogen from the air and grow in symbiosis, or association, with certain leguminous crops, such as alfalfa or the clovers. Moreover, it is possible that lime may have a specific effect on some plants, and it is held by many fruit growers that an ample amount of lime will cause the production of sweeter fruit. Potash is believed to be of especial importance in the production of starch in the growing plants, and phosphoric acid to be important mainly in the formation of seeds or grain, although undoubtedly having other functions in the growing plants. Nitrogen is believed to be taken from the soil, mainly in the form of nitrates, and is elaborated or made over in the plant into various substances, especially the proteids, substances which are best known in the muscular tissues of animals. No substance in the soil produces a more rapid or decided response in the crop than does nitrogen. A ready supply of nitrates is of the utmost importance to green crops, especially during the periods of most rapid growth, and it is desirable to have nitrogenous

¹ Prepared by H. K. Benson, of the Washington Geological Survey.

organic substances in the soil to furnish nitrates by the process of decay, especially for crops other than the legumes.

The methods employed in the analyses of the soils are those of the Association of Official Agricultural Chemists, although a few modifications of procedure which our own experience justified were introduced. The analytical work was done by Mr. F. W. Ashton, assistant chemist, under the supervision of the writer. The soil samples were pestled and sifted through a 1-millimeter sieve, the fine earth only being used in the analysis. The loss on ignition of the soil was generally determined to obtain an approximate idea of the organic matter present. The determination is open to objections, especially where there is much clay or water-holding minerals present, and consequently in a few cases the humus or dark organic coloring matter in the soil was also determined. The presence of a good supply of humus in the soil is believed to be of great importance, as it tends to promote a proper aggregation or clustering of the soil grains, favoring good tilth, the water-holding capacity of the soil, its aeration, and the power to absorb or retain from leaching the dissolved mineral plant nutrients.

The results of the analyses of the various soil types are given in the accompanying table, which is for the most part self-explanatory.

The column headed "Lime requirement" gives the percentages of lime that are necessary to give the soils a neutral reaction. Other analyses of soils from the area are to be found in Bulletins Nos. 13, 55, and 85, State College Experiment Station, Pullman, Wash.

Laboratory No.	Soil type.	Location.	Depth of sample.	Lime.	Phosphoric acid.	Potash.	Loss on ignition.	Lime requirement.
			<i>In.</i>	<i>Perc.</i>				
1	Beverly fine sand.....	Sec. 19, T. 20, R. 23 E.	0-12	0.70	0.14	0.31	4.80	0.006785
2	Naylor silt loam.....	23, 20 N., 28 E.....	0-20	5.22	.08	1.18	9.10	Neg., .02
3	Beverly gravelly fine sandy loam.	16, 16 N., 23 E.....	0-15	.91	.13	.46	1.70	.006785
4	do.....	21, 16, 23.....	0-12	.96	.13	.45	4.10	Neg., .005
5	Quincy fine sandy loam, rock outcrop phase.	25, 16, 28.....	0-12	1.04	.09	.43	3.70	.006785
6	do.....	17, 16, 28.....	0-12	.85	.08	.83	3.90	.006785
7	Red rock fine sandy loam.	33, 16, 26.....	0-20	1.63	.19	.87	6.20	Neg., .005
8	do.....	33, 16, 25.....	0-15	1.93	.16	1.01	6.10	Neg., .02
9	Red rock clay.....	34, 16, 24.....	0-15	2.53	.25	1.16	11.60	Neg., .01
10	do.....	36, 16, 26.....	0-12	8.26	.10	.89	14.70	Neg., .015
11	Quincy fine sandy loam, hardpan phase.	20, 19, 24.....	0-12	.91	.11	1.00	3.90	.006785
12	do.....	35, 19, 23.....	0-12	1.13	.18	.91	4.40	Neg., .01
13	Quincy fine sand, hardpan phase.	35, 17, 24.....	0-20	1.27	.05	.25	2.80	Neg., .01
14	do.....	36, 17, 23.....	0-18	1.32	.03	.28	2.80	Neg., .025
15	Ephrata fine sandy loam.	NW. 23, 19, 27.....	0-15	1.02	.04	.42	4.80	Negative.
16	do.....	35, 19, 28.....	0-15	1.04	.10	.47	4.40	.006785

Laboratory No	Soil type.	Location.	Depth of sample.	Lime.	Phosphoric acid.	Potash.	Loss on ignition.	Lime requirement.
17	Ephrata stony fine sandy loam.	1/43 NW. 27, 20, 26...	0-14	0.96	0.08	0.42	4.90	Negative.
18	do.	Center 9, 20, 27.....	0-12	1.02	.10	.46	5.40	Neg., .01
21	Quincy silt loam.	8, 20, 24.....	0-12	1.06	.12	.50	6.10	Neg., .005
22	do.	12, 26, 23.....	1-12	1.02	.07	.32	6.20	Negative.
23	Quincy very fine sand.	26, 20, 24.....	0-15	.95	.07	.35	3.00	Neg., .01
24	do.	4, 19, 24.....	0-15	1.02	.08	.37	3.40	Negative.
25	Quincy fine sand.	26, 19, 24.....	0-15	1.13	.09	.30	5.80	Neg., .005
26	do.	31, 19, 24.....	0-15	1.13	.07	.31	1.10	Neg., .01
27	Quincy silty fine sandy loam.	15, 20, 23.....	0-12	.77	.12	.38	4.90	.006785
28	do.	34, 29, 23.....	0-12	.83	.11	.41	4.70	.006785
29	do.	1, 16, 26.....	0-15	.95	.119	.273	3.80	Neg., .015
30	do.	36, 17, 25.....	0-20	1.00	.13	.38	4.50	Negative.
31	Winchester sand.	SW. cor. 33, 19, 25....	0-36	1.12	.07	.33	2.70	Neg., .005
32	do.	N. cor. 6, 18, 26.....	0-36	1.04	.10	.33	2.40	Negative.
33	Winchester coarse sand.	3/8 NE. cor. 33, 19, 27.	0-36	1.29	.07	.28	1.80	Neg., .005
34	do.	20, 16, 25.....	0-20	1.15	.04	.23	2.00	Neg., .005
35	Winchester fine sand.	16, 17, 25.....	0-12	.47	.03	.31	2.60	Neg., .01
36	do.	12, 17, 25.....	0-36	1.27	.03	.33	3.10	Neg., .015
38	Ephrata sandy loam.	9, 19, 24.....	0-15	.93	.11	.38	4.20	.006785

These analyses show that the soils of the area are especially high in the mineral elements to which fertility is often ascribed. Since the area is in an arid belt and devoid of vegetation, all of the soils are deficient in organic matter, and for this reason it was considered unnecessary to make nitrogen determinations. This fact is brought out in connection with the low loss in ignition (except in cases where carbonates are present). It will be observed that the variations in the figures for any one type of soil are about the same as the variations between types. Consequently, so far as these analytical data show, the chemical composition of the soil is not a type characteristic. That is to say the main differences in the soils of this area are in their physical and perhaps biological characteristics, and the chemical differences are of importance only in the individual fields, but not between types.

The interpretation of a chemical analysis of a soil is a matter of extreme difficulty. As stated above, these analyses show the soils of the area to be similar in composition as regards the content of lime, potash, and phosphoric acid to good soils of similar areas elsewhere. As a matter of general experience, some authorities, notably Hilgard¹ and Maercker,² have suggested arbitrary standards as to the amounts of the different constituents which soils of different tex-

¹ Soils, E. W. Hilgard, p. 377. The average of the analyses of virgin soils taken from arid regions is here stated as follows: Lime, 1.43 per cent; phosphoric acid, 0.16 per cent; potash, 0.67 per cent; loss on ignition, 3.15 per cent.

² An arbitrary standard for the rating of soils by plant-food percentages was formulated for European soils by Prof. Maercker, of the Halle Station, Germany. While these ratings have failed of general acceptance, even by the soils chemists of Germany, they

tures should have. By these standards the above analyses show the soils of the area to be generally quite satisfactory. But it is impossible to apply such standards in any rigid manner, and it is quite possible for the inexperienced layman or farmer without the necessary technical training to draw quite erroneous conclusions. Therefore, it has not been considered necessary or desirable to tabulate a direct comparison for this report, but to make the simple statement that the data given here, whether by comparison with data for other localities having similar climatic conditions or by other standard methods, show a generally satisfactory state of affairs as regards the chemical composition of the soils of the area.

While the data show that the soils of this area are high in the essential mineral constituents, the low ignition and acidity results point to an absence of organic matter. The first essential in the agricultural development of these soils appears, therefore, to introduce humus and organic matter into the soil. From these data and other considerations it has been found that the soil conditions are favorable for the growth of clovers, alfalfa, and leguminous plants, and the use of these crops as green manures would undoubtedly greatly improve the water holding capacity of the soils. With the high percentages of potash and lime minerals in the soil and a proper moisture supply, there is reason to believe that, so far as soil richness is concerned, such crops as fruits, potatoes, etc., should especially thrive. On certain other types, in which the content of phosphoric acid is normal, grains may be produced. In general, chemical analysis, however, indicates a low phosphoric-acid content, and perhaps this in part explains the reason for the low yields mentioned in another part of this report. While the local differences for each field and crop make it hazardous to give general advice in this connection, it would seem, nevertheless, that the growing of grasses, fruits, and root crops should become highly successful under favorable moisture and climatic conditions. For specific advice the individual farmer will find it advantageous to consult the authorities of the State experiment station.

SUMMARY.

The greater part of the area surveyed, covering 718,720 acres, or 1,123 square miles, lies in Grant County, Wash., the remainder in

are here given for the purpose of indicating an approximation of the quantities of plant-food percentages in soils of various grades:

Grade of soil.	Potash.	Phosphoric acid.	Lime in sandy soil.	Total nitrogen.
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	
Poor soil.....	Below 0.05	Below 0.05	Below 0.05	Below 0.05
Normal soil.....	0.15-0.25	0.10-0.15	0.15-0.20	0.10-0.15
Rich soil.....	Above .40	Above .25	Above .30	Above .25

Adams and Kittitas Counties. Broadly, the area consists of two plains separated by a low range of hills. The northern is known as the Quincy Valley, the southern as the Beverly Plain. The surface ranges from almost level to undulating and hilly. The dividing ridge, the Frenchman Hills, rises some 500 feet above the Quincy Valley.

The principal stream is the Columbia River, which flows along the western boundary of the survey, and Crab Creek, which traverses the eastern and southern parts of the area.

A large proportion of the land suitable for agriculture has been taken up either as homesteads or as desert claims. The greater part of the area is thinly settled, and the areas of Dunesand and Rough broken land are practically uninhabited.

Quincy and Winchester are the principal towns in the northern part of the area. Ephrata, the county seat of Grant County, is located a few miles north of the northeastern boundary of the survey. Beverly, located on the Columbia River, is the principal town in the southern part of the survey.

Transportation facilities are afforded by the main line of the Great Northern Railroad crossing the northern part of the area. The southern part is served by the Chicago, Milwaukee & Puget Sound Railroad.

Prior to 1900 the lands of the area were utilized almost exclusively as a range for horses and cattle. Within the last 10 years agricultural development has progressed rapidly. Dry farming is practiced over the greater part of the area. Wheat and rye are the principal crops grown. The grain is sold at local elevators.

Fruit growing is a promising industry in the northern part of the area.

Potatoes is another crop receiving considerable attention. Alfalfa is grown on a limited acreage under irrigation. Yields of all un-irrigated crops are uncertain, success depending upon adequate rainfall. With irrigation the yields are uniformly high and the quality of the products excellent.

The farms of the area vary in size from 160 to 320 acres. The prices of farming lands range from \$10 to \$100 an acre.

A massive formation of basalt underlies the entire area. This is covered to a variable depth by a mantle of water-laid and wind-blown material from which most of the soils are derived. Narrow belts of alluvial material occur along the valleys of the Columbia River and Crab Creek. The soils of the area have been separated broadly into 21 types.

The soils of the Quincy series, represented by five members, have, where typically developed, deep, compact subsoils. They are considered among the best soils in the area for dry farming and their

topography makes them well adapted to irrigation. The series, however, includes phases very similar in texture to the typical soils of the Quincy series, but underlain at a shallow depth by a calcareous formation overlying the basalt or directly by the basaltic rock. The shallow depth gives insufficient storage room for moisture, and without irrigation the crop yields are very uncertain.

The soils of the Winchester series includes sandy soils which have been drifted into low mounds and ridges. They are characterized by desert vegetation and are but poorly adapted to agriculture without irrigation.

The Ephrata series of soils embraces the gravelly and stony soils of the northeastern part of the area. When irrigated these soils are well adapted to fruit growing and to a variety of general farm crops.

In the Beverly series are included the alluvial soils in the valley of the Columbia River. These soils have good natural drainage and could be irrigated and developed agriculturally without difficulty.

The Red Rock series comprises certain soils in the valley of Crab Creek. These soils contain a large quantity of alkali and are at present cultivated to only a very limited extent.

Rough broken land, Dunesand, and Meadow are mainly nonagricultural types, while the members of the Naylor and Cohasset series are inextensive and not of great agricultural importance.

A large percentage of the total area surveyed is capable of being put under irrigation whenever water can be supplied. The lands have been classified broadly according to their adaptability to irrigation into four classes. (1) Areas where both the soil and topography are well adapted to irrigation; (2) areas where the soils are suitable for agriculture but the topography makes irrigation difficult; (3) areas where irrigation is impracticable; and (4) areas poorly drained but otherwise adapted to irrigation. (See fig. 7.) At the present time the water for irrigation purposes is obtained principally from wells. Only a limited acreage is under irrigation. Small areas along the Columbia River are irrigated with water obtained from that stream. A small acreage in the eastern part of the area is irrigated with water obtained from Moses Lake.

Most of the soils in the area are free from alkali. The accumulation of alkali is due in every case to poor drainage conditions. Soils containing harmful amounts of alkali are found in the upper and lower Crab Creek Valley; in the deep depressions surrounded by areas of rough and broken lands; in the bottoms of Willow Creek and several other large coulees and in the small pot holes which occur in the areas of Dunesand. Water, whether drawn from Moses Lake, Columbia River or from wells, is, so far as shown by analyses of samples collected during the survey, suitable for irrigation under favorable conditions of drainage.

[PUBLIC RESOLUTION—No. 9.]

JOINT RESOLUTION Amending public resolution numbered eight, Fifty-sixth Congress, second session, approved February twenty-third, nineteen hundred and one, "providing for the printing annually of the report on field operations of the Division of Soils, Department of Agriculture."

Resolved by the Senate and House of Representatives of the United States of America in Congress assembled, That public resolution numbered eight, Fifty-sixth Congress, second session, approved February twenty-third, nineteen hundred and one, be amended by striking out all after the resolving clause and inserting in lieu thereof the following:

That there shall be printed ten thousand five hundred copies of the report on field operations of the Division of Soils, Department of Agriculture, of which one thousand five hundred copies shall be for the use of the Senate, three thousand copies for the use of the House of Representatives, and six thousand copies for the use of the Department of Agriculture: *Provided*, That in addition to the number of copies above provided for there shall be printed, as soon as the manuscript can be prepared, with the necessary maps and illustrations to accompany it, a report on each area surveyed, in the form of advance sheets, bound in paper covers, of which five hundred copies shall be for the use of each Senator from the State, two thousand copies for the use of each Representative for the Congressional district or districts in which the survey is made, and one thousand copies for the use of the Department of Agriculture.

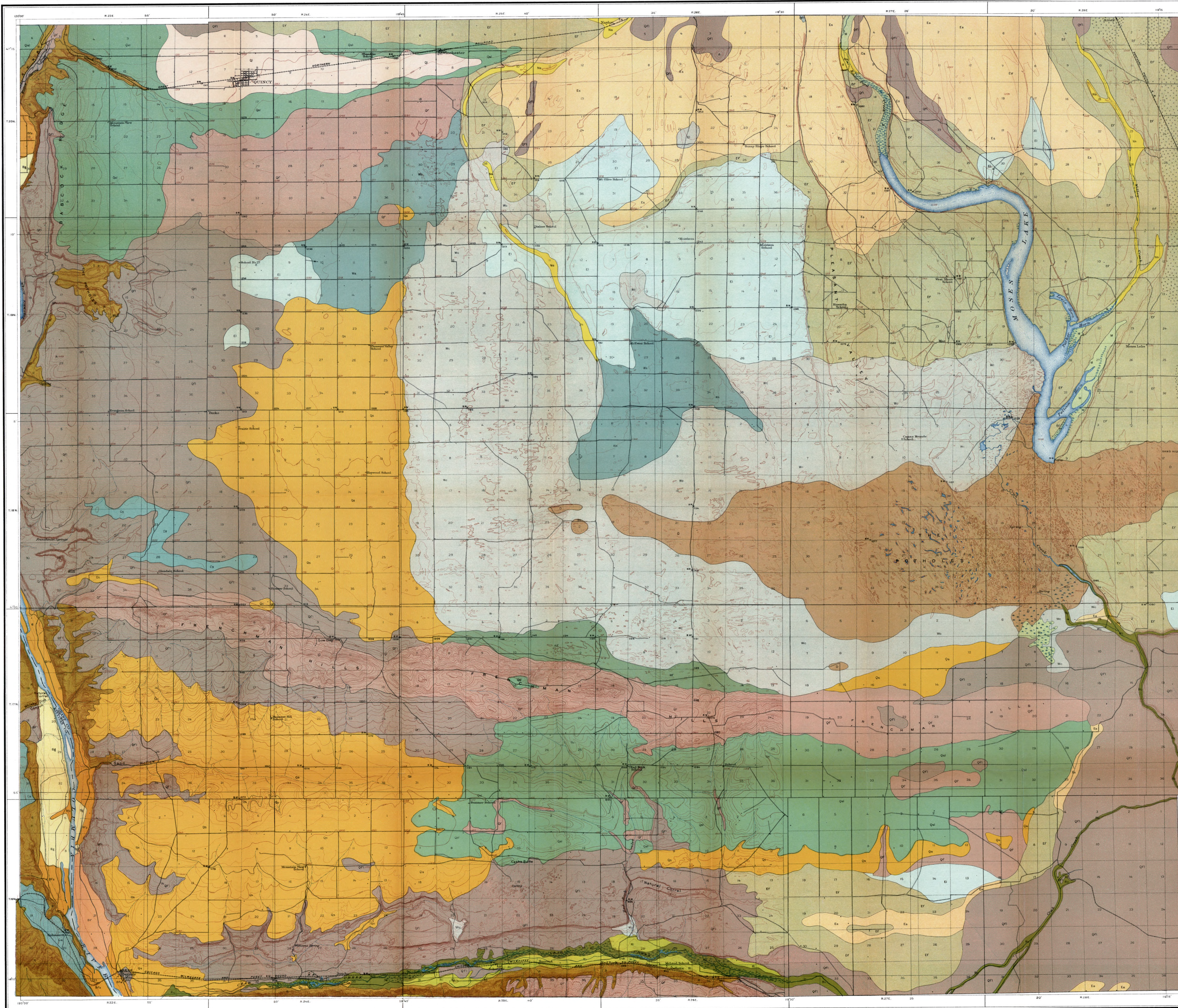
Approved, March 14, 1904.

[On July 1, 1901, the Division of Soils was reorganized as the Bureau of Soils.]

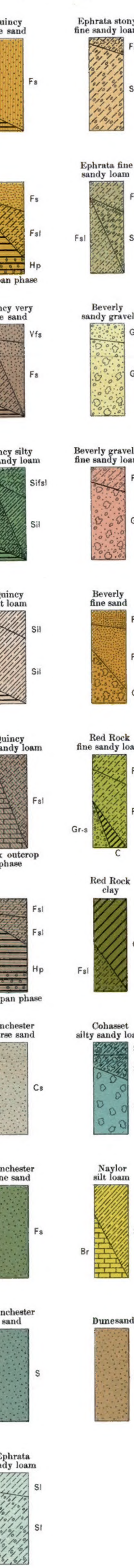
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SOIL PROFILE
(6 feet deep)



LEGEND

